A FAMILIAR INTRODUCTION TO THE ARTS AND SCIENCES,

WITH

ORIGINAL INTRODUCTORY ESSAYS

UPON THE SUBJECT OF EACH LESSON.

FOR THE USE OF SCHOOLS AND YOUNG PERSONS:

CONTAINING A GENERAL EXPLICATION

OF THE

FUNDAMENTAL PRINCIPLES AND FACTS

OF THE SCIENCES,

DIVIDED INTO LESSONS, WITH QUESTIONS SUBJOINED TO EACH,
FOR THE EXAMINATION OF PUPILS.

BY THE REV. J. JOYCE,

AUTHOR OF SCIENTIFIC DIALOGUES, &c.

A NEW EDITION,

REVISED, CORRECTED, AND ENLARGED WITH FOUR ADDITIONAL LESSONS

ILLUSTRATED WITH WOOD ENGRAVINGS.

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PREFACE.

The ingenious Author gives the following recommendatory description of this work. "The object and design of this little work will be obvious, from a very cursory view of its contents. It is intended as introductory to the knowledge of the Arts and Sciences, and it is hoped that it will be found calculated to inform the mind in regard to many of the most important topics with which young persons of both sexes ought to be acquainted.

"In most of our larger schools the study of the sciences is neglected, because the method of teaching them has been so different from that which is resorted to in their other exercises. Children are required to learn by rote the rules of grammar, and the application of these rules is left for future reading. This Introduction is drawn up to facilitate the acquisition of natural and experimental knowledge upon a similar plan. The lessons consist of a series of short sentences to be committed to memory: they all contain facts not only necessary to be known by every well-educated youth, but will be found applicable and of obvious utility in their advanced and more mature studies: and in cases that require them, illustrations of the subject, and figures adapted to it, are subjoined.

"The questions at the end of each lesson, which are numbered, to correspond with the facts to be learned by heart, will afford the instructor an easy method of examination, as well for classes in schools, as for individuals educated under the domestic roof."

The editor of the present improved edition needs to say but little if any thing more: except that to this edition have been added FOUR ORIGINAL LESSONS ON ANATOMY AND PHYSIOLOGY, which it is hoped, will not only render the work more complete, but will afford the youthful reader just ideas concerning the structure of the human body, and the science of life. He can confidently recommend the work to parents, pupils, and instructors, as containing much useful matter, in a cheap and convenient form: and can conscientiously affirm, that it will be found one of the most useful and satisfactory epitomes of human knowledge which has ever yet been published.

Those who are familiar with the labours and difficulties of instruction, will agree with him, that it is not so easy a matter as might at first be supposed, for one intimately acquainted with an art or a science, to introduce another even to the elements of it. He may begin at the beginning, define terms, lay down general principles, deduce particular truths, and go on regularly clearing as he goes, and leaving nothing for an after parenthesis; and yet, only overwhelm the memory, perplex the reason, and ultimately disgust his pupil with the subject. Such a plan is no doubt the most natural to the tutor, and the most proper for any one who, in some degree already acquainted with the subject, would yet wish to refresh his memory upon it. He knows how the terms defined are to come into play and whither the general principles tend; and, therefore, what he is about. He sees that the arrangement is, perhaps, the best that can be adapted for the science abstractedly considered, the one that will most concisely develope truth, and is least liable to lead to repetition; and he has that satisfaction which arises from the contemplation of order.

A mind totally unacquainted with the subject knows nothing of all this. With such an one the editor will

venture to say, that the most concise and least repetitious method may not be the best; the one which most regularly developes the science, not the most philosophical. The most philosophical, because the most natural method, is that which accommodates itself to the mind of the learner; the best teacher is he who can most fully put himself in the pupil's place.

Such a teacher, he imagines, would open a way into any science, by some observation likely to occur to an uninstructed and inquisitive mind; as upon the flight of a stone, the weight of a body, the game of see-saw, in mechanics; the circumnavigation of the globe, or the vicissitude of day and night, in astronomy; the freezing of water, or the working of a steam-engine, in chemistry: no matter what the observation, so that it involves some grand principle of the science. By *leading* questions he will draw the pupil to the developement of the principle, and place it full before him; he will follow, or in seeming to follow, he will in some measure direct the course of the pupil's mind; making observations, tracing consequences, starting objections. In such an introduction to a science, and the familiar conversations which it implies and supposes, the form adopted by the author is obviously very desirable. He lays down the principles of the different arts and sciences in a series of short propositions, which are to be committed to memory, and are divided into lessons of appropriate length: and for its luminous order, its power of making a child think upon the subject, and then aptly following up the train of thought thus excited, its forcible illustrations, and its easy and graceful style, the work in the judgment of the editor stands at the very top of the scientific library of the school-room.

The questions at the end of each lesson, with the figures and illustrations of the subjects, supply the most beneficial exercise that can be employed in the business of tuition. Youth learn nothing effectually but by fre-

quent repetition; a multiplicity of examples, therefore, becomes absolutely necessary: but these examples should be so varied, and the mode of proposing the questions so diversified, as to give the scholar room for the exertion of his faculties, or otherwise no impression will remain on his mind. Elementary treatises are too generally without any practical exercises; or the exercises so similar, that when the pupil has finished one of them the next may be performed without the trouble of thinking. Such examples may pass away the time of the scholar, but they will never instruct him.

Of the PRELIMINARY ESSAYS introduced by the editor he may be permitted to observe, that they will, he trusts, be found to be novel, appropriate, stimulative, and calculated to recommend by just appreciation, and fair and candid representation, the respective subjects to which they are prefixed. For their aim, and their moral tendency, however, he distinctly claims a character of high and honourable solicitude. It has long been allowed that philosophical and scientific subjects afford the greatest, the purest pleasure to a rational mind. It is well observed by a late writer that this does not arise "from any intrinsic value of Science and Philosophy, solely considered, but from the peculiar use to which they may be applied, and without which, they hardly merit the name they have obtained: and this is no other than regulating by them our observations upon the numerous objects of the creation, whereby we may correct any erroneous notions which we may have hitherto encouraged, either concerning them or the OMNIPOTENT BEING by whose will they were formed."

Nature, viewed in its true light, is not a subject of cold and unproductive speculation with regard to morality. The study of its productions and its phenomena, not only enlightens the mind, but warms the heart, by exciting feelings of reverence and admiration, at the sight of so many wonders, bearing such striking charac-

ters of unlimited power and matchless wisdom. Impressed with the truth and force of this sentiment, he has interspersed the expositions of the respective subjects with such observations, and moral reflections, as are calculated to alleviate the mind of the student, to lead him by imperceptible degrees to reflect seriously and justly on the objects around him, and to check an inclination to scepticism which might arise from incautious study, and the mischievous misapplication of scientific phraseology, and modes of reasoning and research.

We may be said to live at one of those remarkable periods which constitute eras in the history of the world. For a series of years preceding the French revolution, the diffusion of knowledge and cultivation of intellect, in France and the neighbouring countries, exceeded in such a proportion the countervailing powers of religion and morality, that all competent judges, acquainted with the state of society, agreed in opinion that some mighty convulsion was at hand. Of the disasters which followed that dreadful event, and the shock which it gave to the civil and religious institutions of the Continent, it is altogether superfluous to speak. But whilst the world was involved in confusion around us, this country, by the blessing of Providence, was not only preserved from destruction, but rose to an eminence of glory and power which it had never attained in former times. In reasoning on the causes of this difference in our favour, we are justified in ascribing our safety to the quantity of virtue and good sense produced in the country by the free constitution of our government, the equal administration of our laws, the principles which regulate our seminaries for the education of youth, and above all to the prevalence of a sound, a pure, a reasonable religion, dispensed and administered alike by a body of clergy both episcopal and dissenting, who from their external condition, and still more from their learning and piety, have an influence on the minds of the people,

not only through the medium of their pastoral functions, but by the effect of their writings, and the estimation which they bear in the community. The danger from that event is now happily past: but when we direct our attention to the systematic culture of intellect introduced in the course of a few years among all classes, we cannot but feel an anxiety lest the balance of society should suffer disturbance from this sudden increase of its momentum. In proportion as these additional energies imparted to the mass of the people are under the direction of good principles, they will give stability to the government, advance the cause of religion and morals, and contribute to the general advantage. But there is no necessary connexion between knowledge and goodness, between the possession of intellectual power and a disposition to apply it to its proper ends.

Nothing need further be said in the assertion or the vindication of the tendency and aims, which the editor avows: they are those of every enlightened minister of education in the kingdom. Preserved from civil and ecclesiastical tyranny, as this highly favoured country has been, the editor looks back with devout gratitude on the stupendous events of the last fifty years; and acknowledges a ruling Providence in the history of Britain: and he confides in the continuance of that Providential protection, as long as his country is not wholly unworthy to hold its place upon this ball of earth.

Upper Holloway,
November 1st. 1839.

T. L.

CONTENTS.

GRAMMAR.

THE UTILITY AND IMPORTANCE OF ITS STUDY.

'They who are learning to compose and arrange their sentences with accuracy and order, are learning, at the same time, to think with accuracy and order.—*Blair*.

GRAMMAR is a term the definition of which can be scarcely said to be philosophically adjusted. The number and the nature of the ideas which it comprehends, are subjects upon which opinions and decisions are conflicting and diversified. A clear and certain exposition of the meaning of the term is perhaps nowhere to be found. In one view it assumes the dignity and claims the consideration of a SCIENCE;—in another its pretensions appear restricted to the more limited proportions of an art. Of the former, *reason* may be considered as the authority, and the standard;—of the latter there is no authority or standard but *custom*. The utility—the importance—and the necessity of the study of this science, or art, are obvious—are self-evident. "As words," says an eminent writer upon it,* "are the signs of our ideas, and the medium by which we perceive the sentiments of others, and communicate our own, and as signs exhibit the things which they are intended to represent, more or less accurately, according as their real or established conformity to those things is more or less exact; it is evident, that in proportion to our knowledge of the nature and properties of words, or of their relation to each other, and of their established connexion with the ideas to which they are applied, will be the certainty and ease with which we transfuse our sentiments into the minds of one another; and that, without a competent knowledge of this kind, we shall frequently be in hazard of misunderstanding others, and of being misunderstood ourselves.

* Introduction to Murray's Grammar, p. 6.

It may, indeed, be justly asserted, that many of the differences in opinion amongst men, with the disputes, contentions, and alienations of heart, which have too often proceeded from such differences, have been occasioned by a want of proper skill in the connexion and meaning of words, and by a tenacious misapplication of language." "All that regards the study of composition," says the eloquent writer upon language and composition whose words we have prefixed to these observations, "merits the highest attention, upon this account, that it is intimately connected with the improvement of our intellectual powers. For we must be allowed to say, that when we are employed, after a proper manner, in the study of composition, we are cultivating the understanding itself. The study of arranging and expressing our thoughts with propriety, teaches us to think, as well as to speak, accurately." One of the best supports which the recommendation of this study can receive, in small compass, may be derived from these sentiments. The great and the important object of language is, to express the various wants and affections of those by whom it is spoken. In the earlier stages of civil society, man is contented with such comforts as are easily procured, and the operations of the mind are circumscribed within narrow limits. His vocabulary is consequently scanty, though at the same time it may be fully adequate to every purpose to which it is applied. But as luxury and refinement advance in their gradual progress, the language of the community becomes more copious and elegant: it not only oversteps its ancient boundaries, but hastens to lay aside its ancient rudeness and barbarism. Material improvements, however, cannot be introduced by any sudden exertion;—they must be the result of experience—and experience time only can bestow.

During the last fifty years. English literature has been enriched with many valuable compositions in prose and verse. Many wise and learned men have made use of our language in communicating their sentiments concerning all the important branches of science and art. All kinds of subjects have been skilfully treated in it, and many works of taste and genius have been written with great and well-deserved success: yet perhaps it will appear, upon a careful view of these compositions, that, whatsoever credit their authors are entitled to, for acuteness of understanding, strength of imagination, delicacy of taste, or energy of expression, there are but few of them that deserve the praise of having expressed themselves in a pure and genuine strain of English. In general

they have preferred such a choice and arrangement of words, as an early acquaintance with some other language, and the neglected study of their own, would naturally incline them to. Sometimes, also, we find them expressing a mean opinion of their native tongue. This, however, I am the less inclined to wonder at, as I am convinced that those only can speak of our language without respect, who are ignorant of its nature and qualities. Perhaps it is as capable of receiving any impressions that a man of taste and genius may choose to stamp upon it, and is as easily moulded into all the various forms of passion, elegance, and sublimity, as any language, ancient or modern.

Some men of eminence in letters, having seen how well the fashionable world has succeeded in imitating the manners of our neighbours, the French, have endeavoured to raise themselves into reputation by importing their forms of speech; and, not contented with the good old English idiom, have dressed out their works in all the tawdriness of French phraseology. But this injudicious fashion of adulterating our language with foreign mixtures, is more especially the case with respect to the Latin:—to the laws of which, many of our writers, and indeed some also of our grammarians, have so strenuously endeavoured to subject our language, that an old author's prophecy seems at length to have come to pass, and "we are now forced to study Latin in order to understand English."* The complaint was not new in his time—but the practice complained of is now become more frequent and more extensive than ever. Our elegant and idiomatic satirist, POPE, ridicules that

> "——— easy Ciceronian style,
> So Latin, yet so English all the while."
>
> *Pope's Epilogues to Satires.*

Not only Latin words, but Latin idioms, are now invading us with so much success, that, do what we can, I fear we must submit to the yoke; and, as our country was formerly compelled to become a province of the Roman empire, so must our language sink at last into a dialect of the Roman tongue. This event has been much hastened of late years. Some men, whose writings do honour to their country and to mankind, have, it must be confessed, written in a style that no Englishman will own; a sort of Anglicised Latin, and chiefly distinguished from it by a trifling difference of termination: yet so excellent are these works in other respects, that a man might deserve well of the public who would take the trouble of

* Brown's Vulgar Errors.—*See Preface.*

translating them into English. As I do not notice these alterations in our language in order to commend them, I shall not produce any particular instances; I shall content myself with supporting the fact by the evidence of the greatest critic and master of it that ever lived. In the preface to his Dictionary, Dr. Johnson says, "so far have I been to grace my page with modern decorations, that I have studiously endeavoured to collect my examples and authorities from the writers before the Restoration, whose works I regard as the WELLS OF ENGLISH UNDEFILED—as the pure sources of genuine diction. Our language, for almost a century, has, by the concurrence of many causes, been gradually departing from its ancient Teutonic character, and deviating towards a Gallic structure and phraseology; *from which it ought to be our endeavour to recall it;*—by making our ancient volumes the groundwork of our style, admitting among the additions of later times only such as may supply real deficiencies, such as are readily adopted by the genius of our tongue, and incorporate easily with our native idioms."

In his preface to the Works of Shakspeare, we also find the following very applicable sentiments:—"I believe there is in every nation a style that never becomes obsolete, a certain mode of phraseology so consonant and congenial to the principles of its respective language, as to remain settled and unaltered. The polite are always catching modish innovations, and the learned depart from established forms of speech in hopes of finding or making better: those who write for distinction, *forsake the vulgar, when the vulgar is right;* but there is a conversation, above grossness and below refinement, where propriety resides, and where Shakspeare seems to have gathered his comic dialogue. He is, therefore, more agreeable to the ears of the present age than any other author equally remote, and, among his other excellences, deserves to be studied as ONE OF THE ORIGINAL MASTERS OF OUR LANGUAGE." These passages I have inserted, because such a testimony from this great man will, at least, be thought *impartial* by every person acquainted with the characteristics of his style.

The alterations in our language here mentioned are certainly not for the better:—they give the phraseology a disgusting air of study and formality: they have their source in affectation, not in taste: yet novelty has its attractions. Though such exotic terms and phrases as are here referred to, are not better than our homebred English, yet their newness gives them a spurious sort of beauty:—though they

do not really enrich the dress of our thoughts, yet they are a kind of tinsel ornaments, admired because they glitter, gild, and glare. The writers I allude to may, perhaps, have succeeded in giving our language a higher polish; but have they not also curtailed and impoverished it? Perhaps they may have cleared it of some cant terms, low phrases, and awkward constructions; but what they may have gained in accuracy, have they not lost in variety? Have they not reduced all kinds of composition to an insipid uniformity? Is not the spirit of our language lowered, its freedom cramped, and its range of expression narrowed?

I shall not be required to prove this opinion by such of my readers as are acquainted with the works of Hooker, Taylor, Swift, Pope, Addison, and Dryden, the boast and glory of English literature;—with the prose of Cowley, and with Shakspeare's "immortal wit." However, the prevalence of fashion is so strong, that all resistance to this adulteration of our language may be ineffectual: and it is well worthy of notice, that every polite nation hitherto distinguished in literature, has, after a certain period, declined in taste and purity of composition. The later Greek writers are known by the diminutive term, "*Græculi,*"—and the Augustan age denotes an æra before the Latin tongue was vitiated and spoiled by vain refinements and affected innovations. To prevent a similar decline in the French language, the French Academy endeavoured to render it at once more pure and more durable; but the republic of letters is a true republic, in its disregard to the arbitrary decrees of an usurped authority. Perhaps such an institution would do still less with us. Our critics are allowed to petition, but not to command: and why should their power be enlarged? The laws of our speech, like the laws of our country, should breathe a spirit of liberty: they should check licentiousness, without restraining freedom. The most effectual method of preserving our language from decay, and preventing a total disregard to the Saxon part of it, is to *change our present mode of education.*

Children are generally taught the grammar of a foreign tongue before they understand that of their own: or if they chance to be instructed in the principles of their native tongue, they learn them from some system that does little more than fetter it with the rules of construction drawn from another language. Dr. Lowth, in his preface, has taken notice of this circumstance. He says—"A grammatical study of our own language makes no part of the ordinary method of instruction which we pass through in our childhood, and it is very sel-

dom that we apply ourselves to it afterwards. Yet the want of it will never be effectually supplied by any other advantages whatsoever. Much practice in the polite world, and a general acquaintance with the best authors, are good helps; but alone will hardly be sufficient: we have writers who have enjoyed these advantages in their full extent, and yet cannot be recommended as models of an accurate style. Much less, then, will what is commonly called learning, serve the purpose; that is, a critical knowledge of ancient languages, and much reading of ancient authors. The greatest critic and most able grammarian of the last age, was frequently at a loss in matters of ordinary use and common construction in his own vernacular idiom."*

The design of the following lessons is to teach the grammar of the English tongue—not by arbitrary and capricious rules, and much less by such as are taken from the customs of other languages—but by a methodical collection of observations and principles, comprising all those current phrases and forms of speech which are to be found in our best and most approved writers and speakers, arranged in a series of short propositions, which are to be committed to memory; and they will be found to recommend themselves, as containing a large quantity of useful elementary matter, in an impressive and most convenient form. It is certainly the business of a grammarian to find out, and not to make, the laws of a language. In this work the author does not assume the character of a legislator, but appears as a faithful compiler and abridger of the scattered laws. He does not presume to regulate the customs and fashions of our speech, but only notes and collects them.

It matters not what these customs and fashions owe their birth to, the moment they become general they are the laws of the language; and a grammarian may remonstrate, but can do no more, how greatly soever he may disapprove. From his opinions and precepts an appeal may always be made to the tribunal of use, as to the supreme authority and last resort: in language, as in law, "*communis error facit jus*"—the common error makes the law. By the general consent of a nation, certain sounds and certain written signs, together with their inflections and combinations, come to be used as denoting certain ideas and their relations; and the man that chooses to deviate from the custom of his country in expressing his thoughts, is as ridiculous as though he were

* The learned person here alluded to by Dr. Lowth is the celebrated scholar and critic, Dr. Bentley.

to walk the streets in a Spanish cloak, or a Roman toga. Perhaps he might say, these garments are more elegant and more commodious than a suit of English broad-cloth; but I believe that this excuse would hardly protect him from derision and disgrace.

Besides the principal purpose for which these lessons were written (that of instructing youth), I hope the perusal of them may not be useless to those who are already acquainted with polite literature. Much reading and good company are supposed to be the best methods of getting at the niceties and elegancies of language; but this road is long and irksome. It is certainly a safer and a readier way to sail by compass than to rove at random: and any person who wished to become acquainted with the various productions of nature, would do better to study the system of our best naturalists, than to go wandering about from land to land, lighting here upon one, and there upon another, merely out of a desire to see them all. These lessons also may be useful to those foreigners who wish to learn the English tongue,—as they will be found to contain the most general and useful Anglicisms, and all those phrases and peculiarities which form the characteristics of our language.

I will not take upon me to say that we have no grammar capable of teaching a foreigner to read our authors, but this I am sure of, that we have none by which he can be enabled to understand our conversation.

LESSON THE FIRST.

INTRODUCTION.

1. Grammar is the art of speaking and writing any language with propriety.

2. *General Grammar* teaches the principles which are common to all languages.

3. The grammar of any particular language teaches the principles and rules peculiar to that language.

4. All *art* is founded on science, or on the knowledge of the materials employed in it.

5. Every art has a *subject* peculiar to itself, of the properties of which it treats.

6. The subject of *grammar* is composed ot articulate sounds.

7. There are two kinds of subjects, namely, simple and compound.

8. A subject is simple when it is *not* made up of parts.

9. A compound subject is composed of more parts than one: thus language, or discourse, is compound, being made up of sentences.

10. The dividing of a thing into its parts is called analysis or decomposition.

11. Sentences may be resolved into words; words into syllables; and syllables into letters.

12. Grammar begins with the properties of letters, and ends with the properties of sentences, and is commonly divided into four parts—viz., Orthography, Etymology, Syntax, and Prosody.

QUESTIONS FOR EXAMINATION.

1. What is grammar?
2. What is meant by general grammar?
3. What does the grammar of any particular language teach?
4. On what is art founded?
5. What is peculiar to every art?
6. What is the subject of grammar?
7. How many kinds of subjects are there, and what are they?
8. What is meant by a simple subject?
9. What is meant by a compound subject?
10. What is meant by analysis or decomposition?
11. How are sentences resolved?
12. With what does grammar begin and end, and how is it commonly divided?

LESSON THE SECOND.

OF SOUNDS—LETTERS—SYLLABLES—AND WORDS.

1. An *articulate sound* is the sound of the human voice formed by the organs of speech, and which is associated with, and represented by, a letter or representative sign.

2. The *organs of speech* are the tongue, the teeth, the lips, and the palate.

3. A letter is the mark or sign of an articulate sound, and is the least part of a word: it is called also a first principle, because all language is formed of letters.

4. There are twenty-six letters in the English alphabet, which are divided into vowels and consonants.

5. A *vowel* is a letter representing a sound that can be perfectly uttered by itself: such as *a*, *e*, *i*, *o*, *u*, and sometimes *w* and *y* are vowels: which are formed without the help of any other sound.

6. A *consonant* is a letter representing a sound that cannot be perfectly uttered without the aid of a vowel: as *b*, *d*, *f*, *l*; which require vowels to express them fully.

7. *W* and *y* are consonants when they begin a word, but vowels in every other situation.

8. A *diphthong* is the union of two vowels in one sound, and pronounced by a single impulse of the voice: as *ea* in beat; *ou* in sound.

9. A *syllable* is a sound represented by one or more letters, either simple or compounded, produced by a single impulse of the voice, and constituting a word or part of a word, as *a*, *an*, *ant*, *horse*, &c.

10. *Words* are articulate sounds, used as signs of our ideas. See Logic.

11. A word of one syllable is termed a *monosyllable*.

12. *Spelling* is the art of rightly dividing words into their syllables, or of expressing a word by its proper syllables and letters.

It is of very great importance to obtain, early in life, a clear, distinct, and accurate knowledge of the sounds of the elements, or the first principles of language. The sentiments of a very judicious and eminent writer (Quinctilian) respecting this most important and depreciated part of grammar, deserve the serious attention of the student. "Let no person despise," says he, "as inconsiderable, the elements of grammar, because it may seem to them a matter of small consequence to show the distinction between vowels and consonants, and to divide the latter into liquids and mutes. But they who penetrate into the innermost parts of this temple of science, will there discover such refinement and subtilty of

matter, as are not only proper to sharpen the understandings of young persons, but sufficient to give exercise for the most profound knowledge and erudition."

QUESTIONS FOR EXAMINATION.

1. What is an articulate sound?
2. What is meant by the organs of speech?
3. What is a letter?
4. How many letters are there, and how are they divided?
5. What is meant by a vowel?
6. How do you define a consonant?
7. In what cases are *w* and *y* consonants, and when are they vowels?
8. What is meant by a diphthong?
9. What do you mean by a syllable?
10. What are words?
11. What is a monosyllable?
12. What is spelling?

LESSON THE THIRD.

OF ARTICLES AND NOUNS.

1. In English there are nine sorts of words, or, as they are commonly called, parts of speech, namely, the *article*; the *noun*, or substantive; the *adjective*; the *pronoun*; the *verb*; the *adverb*; the *preposition*; the *conjunction*; and the *interjection*.

2. An article is a word prefixed to nouns to point them out, and to show how far their signification extends.

3. The articles are *a*, *an*, *the*: *the* is definite; *a* and *an* indefinite: thus we say *the house*, when we mean any particular house; *a horse*, or *an acorn*, when we refer to one generally.

4. A *noun*, or, as it is sometimes called, a substantive, is the name of any person, place, or thing, as *James*, *London*, *land*, *leisure*.

5. A noun may be known by taking an article before it, as *a book*; *an owl*; *the moon*: or by its making sense of itself, as *virtue*, *poverty*, *wealth*.

6. Nouns are either *proper* or *common*:—*proper* nouns are the names appropriated to individuals, as *Charles*, *Paris*, *Thames:* and *common* nouns denote the species or kinds of things containing many sorts, as *a man*, *a city*, *a river:* thus *Paris* is a proper noun, being a name appropriated to a particular city; but *city* is a common noun, as understood of any city.

7. All nouns are of the third person when *spoken of;* and of the second when *spoken to.* Examples.—*The men run; trees are green:* here *men* and *trees* are spoken *of*, and are of the third person. *Men and citizens listen to my words:* in this case *men* and *citizens* are spoken *to*, and are of the second person.

8. To nouns belong person, gender, number, and case.

9. *Gender* is the distinction of nouns, with regard to sex; there are three genders, the masculine, feminine, and neuter.

10. The *masculine* gender denotes animals of the male kind; as a *man*, a *horse*, a *bull.*

11. The *feminine* gender denotes animals of the female kind; as a *woman*, a *mare*, a *cow.*

12. The *neuter* gender denotes objects which are neither male nor female; as a *field*, a *plough*, a *spade.*

13. Some substantives, naturally neuter, are, by a figure of speech, converted into the masculine or feminine gender; as when we say of the *sun*, *he* is setting; and of a *ship*, *she* sails well.

14. The gender is distinguished, (1.) by *different words*, as *man*, *woman; brother*, *sister.* (2.) By a *difference of termination*, as *lion*, *lioness; master*, *mistress.* (3.) By another word, a noun, pronoun, or adjective, being prefixed to the noun, as *man-servant*, *maid-servant; male-child*, *female-child.*

QUESTIONS FOR EXAMINATION.

1. How many parts of speech are there, and what are they?
2. What do you mean by a noun?
3. What is meant by an article?
4. What are the articles, and how are they distinguished?

5. How is a noun known ?

6. How many kinds of nouns are there, and how are they distinguished ?

7. Explain by the examples which are nouns of the third person, and which of the second ?

8. What belong to nouns ?

9. What is meant by gender, and how many genders are there ?

10. What does the masculine gender denote ?

11. What does the feminine gender denote ?

12. What is meant by the neuter gender

13. How are substantives naturally neuter converted into the masculine or feminine genders ?

14. How are genders distinguished ?

LESSON THE FOURTH.

NOUNS CONTINUED.

1. There are two numbers belonging to nouns, the *singular* and the *plural*. The singular is used to express one object : and the plural is used when two or more are to be expressed.

2. The plural is generally formed, (1.) by adding *s* to the singular, as *river, rivers*. (2.) By adding *es* when the singular ends in *ch*, *s*, *sh*, *x*, and *z*, as *church, churches ; kiss, kisses ; lash, lashes , fox, foxes*. (3.) By adding *ves* to nouns ending in *f*, or *fe*, as *calf, calves ; knife, knives*. (4.) When nouns end in *y*, the plural is formed by changing *y* into *ies*, as *fly, flies*.

3. There are many exceptions to these general rules, as *ox, oxen ; muff, muffs ; chief, chiefs ; key, keys ; goose, geese ; foot, feet*, &c.

4. Some nouns admit of a singular termination only, as *wheat, steel, sloth ;* some have the plural termination only, as *bellows, scissors, ashes ;* and in some nouns the singular and plural are the same, as *deer, sheep*, &c.

5. *Case* is the variation of nouns, serving to express the different relations they bear to each other.

6. English nouns have three cases, the *nominative*, the *possessive*, and *objective :* the possessive is some-

times called the genitive case; and the objective, the accusative.

7. The *nominative* expresses the name of a thing, or the *subject* of the verb; as the boy runs, the girls play.

8. The *possessive* denotes the relation of property or possession, and is formed by adding *s* to the nominative, with an apostrophe before it, as *Solomon's wisdom*, the *cow's crib*. When the noun ends in *s*, the apostrophe only is added, as the *stationers' arms*, the *drapers' company*.*

9. The *objective* case expresses the *object* of an action, or of a relation, and generally follows an active verb, or a preposition: as Charles teaches James; Charles and James live in London.

10. Nouns are declined in the following manner:—

	Singular.	Plural.
Nominative.	The man.	The men.
Possessive.	The man's	The men's.
Objective.	The man.	The men

11. The nominative and objective are spelt alike; but in a sentence the nominative comes before the verb, and the objective after a verb active, or preposition.

QUESTIONS FOR EXAMINATION.

1. How many *numbers* are there belonging to nouns, and what do they express?
2. What are the rules in forming the *plural* number?
3. Mention the *exceptions* to the general rules?
4. Do all nouns admit of *singular* and *plural* terminations?
5. What do you mean by *case*?
6. How many cases are there?
7. What does the nominative case express?
8. What does the possessive case denote?
9. What does the objective case denote?
10. Decline the noun man: also by the same rule the nouns father, mother, brother, and sister.
11. Point out the distinction between the nominative and objective cases.

* Sometimes, also, when the singular terminates in *ss*, the apostrophic *s* is not added, as "For goodness' sake"—"For righteousness' sake."

LESSON THE FIFTH.

OF ADJECTIVES.

1. An *adjective* is a word added to a substantive to express its quality, or property; as, a *good* man; a *green* gate.

2. English adjectives admit of variation, and change their terminations on account of comparison.

3. There are three degrees of comparison; the positive, the comparative, and superlative.

4. The *positive* simply expresses the quality of any object, without any increase or diminution; as *hard*, *wise*, *small*.

5. The *comparative* increases or diminishes its quality; as *harder*, *wiser*, *smaller*.

6. The *superlative* expresses its quality in the highest or lowest possible degree; as *hardest*, *wisest*, *smallest*.

7. The *positive* is changed into the *comparative* by the addition of *r*, or *er*; as *wise*, *wiser*; *hard*, *harder*: and into the *superlative* by adding *st*, or *est*; as *wise*, *wisest*; *hard*, *hardest*.

8. The adverbs *more* and *most*, placed before an adjective, have the same effect, as *more* wise, *most* wise.

9. *Monosyllables* are, for the most part, compared by *er* and *est*; as *hard*, *harder*, *hardest*; and *dissyllables* by *more* and *most*; as *modest*, *more modest*, *most modest*.

10. Some adjectives are composed very irregularly; as

Good,	better,	best.
Little,	less,	least.
Many,	more,	most.
Bad,	worse,	worst.

11. Some comparatives form the superlative by adding *most*; as *fore*, *former*, *foremost*; *up*, *upper*, *uppermost*: and some adjectives have only two degrees of comparison; as *under*, *undermost*.

QUESTIONS FOR EXAMINATION.

1. What is meant by an adjective?
2. On what account do adjectives change their terminations?

3. How many degrees of comparison are there?
4. What is meant by the positive?
5. What is the effect of the comparative?
6. What is the effect of the superlative?
7. How are the comparatives and superlatives formed?
8. Is the same effect produced by any other words?
9. In what case are the terminations *er* and *est* used, and in what the words more and most?
10. Give some instances in which adjectives are compared irregularly.
11. Are there any other irregularities with regard to comparatives.

LESSON THE SIXTH.

OF PRONOUNS.

1. A *pronoun* is a word used instead of a noun, and enables us to avoid a too frequent repetition of the same: thus we say, "*he* or *she* did this, or that," instead of expressly naming the person.

2. There are three kinds of pronouns, the personal, relative, and adjective.

3. There are five *personal* pronouns: namely, *I*, *thou*, *he*, *she*, *it*, which are singular; with their plurals, *we*, *ye* or *you*, *they*.

4. The third person singular of the pronouns, *he*, *she*, *it*, is the only one that admits of a distinction of gender. *He* is masculine; *she* is feminine; *it* is neuter.

5. Pronouns, like nouns, have two numbers, and three cases; viz., the singular and plural, and the nominative, possessive, and objective. They are mostly different from each other.

6.

		Singular.	Plural.
First person.	*Nom.*	I.	We.
	Poss.	Mine.	Ours.
	Obj.	Me.	Us.
Second person.	*Nom.*	Thou.	Ye *or* you.
	Poss.	Thine.	Yours.
	Obj.	Thee.	You.
Third person.	*Nom.*	He, she, it.	They, theirs, them.
	Poss.	His, hers, its.	
	Obj.	Him, her, it.	

7. In pronouns the *first* person is the *speaker;* the *second* is the person *spoken to;* and the *third* is the person *spoken of.*

8. Relative pronouns are such as relate to some word or phrase going before, which is called the antecedent: these are, *who*, *which*, and *that*. *Who* is applied to persons; *which*, to animals and inanimate things; *that* is applied both to persons and things, and prevents the too frequent repetition of who and which.

9. *What* is a compound relative, including both the antecedent and relative, and is equivalent to *that which*. "This is what I wished;" that is, "the thing which I wished."

10. *Who*, *which*, *what*, are called interrogatives, when used in asking questions. The cases of *who* are. Nom. *Who*. Poss. *Whose*. Obj. *Whom*.

11. Adjective pronouns are of a mixed nature, participating the properties both of pronouns and adjectives; and are subdivided into four sorts, namely, the possessive, distributive, demonstrative, and the indefinite.

12. The *possessive* are those which relate to possession, or property: these are, *my*, *thy*, *his*, *her*, *our*, *your*, *their*.

13. The *distributive* pronouns are those which denote the persons or things which make up a number, as taken separately and singly: these are, *each*, *every*, *either*.

14. The *demonstrative* pronouns are those which precisely point out the subjects to which they belong: as *this* and *that; these* and *those*.

15. The *indefinite* are those which express their subjects in an indefinite or general manner: as *some*, *other*, *any*, *one*, *all*, *such*.

QUESTIONS FOR EXAMINATION.

1. For what are pronouns used?
2. How many kinds of pronouns are there?
3. Which are the personal pronouns?
4. To which of the persons of pronouns has gender respect?
5. How many cases have pronouns?

6. Decline the personal pronouns.

7. To whom do the first, second, and third persons of pronouns relate?

8. What are relative pronouns?

9. Explain the use of the relative *what.*

10. Which are the interrogatives, and what are the cases of the pronouns?

11. Into what are adjective pronouns divided?

12. What are the possessive pronouns?

13. What are the distributive pronouns?

14. What are the demonstrative pronouns?

15. What are the indefinite pronouns?

LESSON THE SEVENTH.

OF VERBS.

1. A verb is a word that signifies *to be, to do,* or *to suffer:* as *I am, I love, I am loved.*

2. There are three kinds of verbs;* transitive, intransitive, and auxiliary or connecting verbs.

3. A transitive verb is when the action passes over to, or affects some other person or thing; as *I dig the ground.*

4. An intransitive verb is one in which the action does not pass over to, nor affect any other person or thing; as *I am loved, I run, I walk,* &c.

5. A verb transitive supposes a person or thing that acts, and a person or thing that is affected by the action: thus, *I dig the ground,* there is the person who acts, and the ground acted upon.

* The usual distribution of *verbs* is into three kinds—active, passive, and neuter The sole reason why such distinctions were ever applied to the English language seems to be, that they previously existed in connexion with the Latin. They are, however, discarded by the more philosophical grammarians, who, instead, distinguish them into transitive and intransitive. The only utility in this distinction is its subserviency to a grammatic rule, which says verbs active, or verbs transitive, govern the objective case, as truth ennobles *her,* she comforts *me,*&c. Here ennobles is considered as a verb transitive, because the action passes over to the object; and if that be represented by a pronoun, it must be in what is called the objective, or the accusative case: but such instances as I sit, he lives, they sleep, are denominated intransitive, because the effect is confined within the subject or nominative of the verb, and does not pass over to any object.

6. The person or thing that acts is called the *agent*, and the person or thing acted upon is called the *object;* as when we say, *Alexander conquered Darius*, Alexander is the agent and Darius the object.

7. A verb transitive supposes an agent and an object:—a verb intransitive implies an agent, and has no object, as *I walk;* but it may be followed by a noun of the same signification; as *I run a race.*

8. To find the agent of a transitive verb, we ask the question, *who*, or *what*, before the verb; as *Who* conquered Darius? answer, Alexander, the agent. To find the object, you ask the question, *Whom* did Alexander conquer? answer, Darius, the object.

9. The radical form of verbs, or that from which all the modifications of them are derived, is that in which they follow the particle *to;* as *to love*, *to run.*

10. The auxiliary, or connecting verbs are, *am*, *are*, *be*, *become*, *is*, *was*, *were:* and they serve to connect qualities with their subjects, or are used in conjunction with other verbs; as *I am cold; John and James are going to London; God is good.*

11. The person or thing preceding a connecting verb is called the *subject*, and a quality or thing coming after it is called the *predicate.*

QUESTIONS FOR EXAMINATION.

1. How do you define a verb?
2. How many kinds of verbs are there?
3. What is meant by a transitive verb?
4. What is meant by an intransitive?
5. What does a transitive verb imply?
6. What do you mean by the agent and object?
7. What does a verb transitive imply, and what a verb intransitive?
8. How do you find the agent and object of a transitive verb?
9. What is the radical form of verbs?
10. Which are the auxiliary, or connecting verbs, and what is their use?
11. What is meant by the subject and predicate?

LESSON THE EIGHTH.

OF VERBS, CONTINUED—AND PARTICIPLES.

1. The properties of verbs are *mood, tense; number,* and *person.*

2. The *mood,* is the mode or manner of expressing the sense of the verb: there are four moods, viz., the *indicative, imperative, subjunctive,* and *infinitive.*

3. The sense of the indicative is certain, and it simply indicates or declares a thing; as *I walk, he is beaten.* Or it asks a question, *Does he walk? Was he hurt? Have you learnt?*

4. The imperative expresses a command, an entreaty, or permission: as *go, run to the village; remain with us; act as you please: go, run, remain, act:*—these are all in the imperative.

5. The subjunctive mood expresses a thing conditionally, and is preceded by a conjunction expressed or understood; or its signification is uncertain and contingent, as under a condition, wish, supposition, &c.: as *I will love him, though he reprove me. Were he more kind, he would be more amiable:* that is, *if* he were more kind, &c.

6. The infinitive mood is preceded by the preposition *to,* and is not limited by person or number, but expresses a thing in a general and unlimited manner; as *to act, to run, to be loved.*

7. The tenses mark the division of time: they are, (1.) The present, expressing the *time now:* (2.) The perfect, expressing *time past:* (3.) The future, expressing *time to come.*

8. In verbs there are *two numbers;* singular and plural; and *three persons,* viz., first, second, and third, singular and plural, answering to the pronouns, *I, thou, he; we, ye* or *you, they.*

9. All words whatever, except *I, thou, we, ye* or *you,* are of the third person.

10. The second person of the present tense, indicative mood, is formed by adding *st* or *est,* to the first

person; as love, lov*est;* walk, walk*est,* according as the verb has, or has not, the final *e*. In the plural number there is no change: as *we love; ye* or *you love; they love.*

11. The third person is formed by adding to the first *th* or *eth;* as love, love*th;* walk, walk*eth.* But *th* or *eth* is often changed to *s:* as he loveth, or loves; he walketh, or walks.

12. The first and third person of the perfect tense, are formed by adding *d* or *ed* to the first person of the present, according as the verb has or has not the final *e;* as love, love*d;* walk, walk*ed.*

13. The second person is formed by adding to the first person *est,* which is usually changed into *st;* as loved, loved*est,* loved*st.*

14. The future tense is known by the sign of shall or will; as *I shall or will love, thou shalt or wilt love.*

15. The *imperative* mood has only one tense, the present; and has the auxiliary verb *let* as its sign.

16. The *subjunctive* mood has two tenses, the present and past: and has the signs may, can, might, could, would, should.

17. The *infinitive* mood has two tenses, the present and past; as *to love, to have loved.*

18. Participles are certain forms of the verb, and are so called from participating the active properties of verbs, and the form and construction of adjectives. They are the present, and the past or perfect.

19. The *present* participle is formed by adding *ing* to the verb; as walk, walk*ing:* if the verb end in *e,* the *e* is dropped; as love, lov*ing;* make, mak*ing; be* makes *being,* and *dye dyeing.*

20. The *perfect* participle is formed by adding *d* or *ed* to the verb; as love, love*d;* walk, walk*ed.* But there are many exceptions; as write, written; draw, drawn; bind, bound; &c.

21. The perfect tense, and perfect participle of verbs, having only one syllable, and ending in *d* or *t,* are the same as the present; as read, *read,* having *read;* hurt, *hurt,* having *hurt.*

22. In verbs ending in *d*, preceded by a diphthong, one of the vowels is dropped in the perfect tense and perfect participle; as bleed, *bled*, having *bled*; feed, *fed*, having *fed*.

23. In verbs ending in *ing* and *ch*, the perfect tense and perfect participle ends in *ght*; as bring, brou*ght*, teach, *taught*.

24. Many verbs have the perfect tense and perfect participle ending in *t*; as dwell, dwel*t*; leave, lef*t*; pass, pas*t*.

25. Auxiliary verbs are used with other verbs to ascertain the time and other circumstances of an action with greater precision; and in forming the tenses, the change of termination is confined to the auxiliary; as I *do* love; thou *dost* love; he *doth* love, &c. I *am* loving, thou *art* loving.

QUESTIONS FOR EXAMINATION.

1. What are the properties of verbs?
2. What is meant by the mood?
3. What is meant by the indicative mood?
4. What is meant by the imperative mood?
5. What is meant by the subjunctive mood?
6. How is the infinitive mood known?
7. For what are the tenses used?
8. How many numbers and persons are there?
9. Of what person are words in general?
10. How is the second person of the present tense, indicative mood, formed?
11. How is the third person formed?
12. How are the first and third persons of the perfect tense formed?
13. How is the second person formed?
14. How is the future tense known?
15. How many tenses has the imperative mood, and what is its sign?
16. How many tenses has the subjunctive mood, what are its signs?
17. What are the tenses of the infinitive mood?
18. What are participles and why so called?
19. How is the present participle formed?
20. How is the perfect participle formed?

21. In what case are the perfect tense and perfect participle the same as the present?

22. In what case is a vowel dropped in the perfect tense and perfect participle?

23. In what verbs do the perfect tense and perfect participle end in *ght*?

24. In what words do the perfect tense and perfect participle end in *t*?

25. How and for what purpose are auxiliary verbs used?

LESSON THE NINTH.

OF ADVERBS, PREPOSITIONS, CONJUNCTIONS, AND INTERJECTIONS.

1. An *adverb* is a part of speech joined to a verb an adjective, and sometimes to another verb, to express some quality or circumstance respecting it; as he writes *well;* a *truly* benevolent man; he fought *very bravely*.

2. Some adverbs admit of comparison; as soon, sooner, soonest: and those ending in *ly* are compared by the words *more* and *most;* as godly, more godly, most godly.

3. *Prepositions* express the relation that one word has to another; as he went *to* Cambridge; he walked *from* London to York *in* four days; they are supported *by* industry.

4. *Conjunctions* join words and sentences together, and show the manner of their dependence upon one another; as John *and* James live in the country; I will run, *if* you wish it. Conjunctions are either conjunctive, as *and;* or *disjunctive*, as *nor*.

5. *Interjections* are broken or imperfect words, denoting some emotion or passion of the mind; as *alas!* I dread to hear the news; *oh!* how anxious I am!

QUESTIONS FOR EXAMINATION.

1. What do you mean by an adverb?
2. How are adverbs compared?
3. Of what use are prepositions?
4. Of what use are conjunctions?
5. What are interjections?

LESSON THE TENTH.

SYNTAX.

1. Syntax treats of the agreement and construction of words in a sentence.

2. A sentence is an assemblage of words forming a complete sense: the principal parts of which are the subject, the attribute, and the object.

3. The *subject* is the thing chiefly spoken of; the *attribute* is the thing or action affirmed or denied of it; and the *object* is the thing affected by such action: as "Alexander pursued Darius;" "Alexander" is the subject; "pursued" the attribute; "Darius" the object.

4. The subject is the nominative to the verb, and usually goes before it; and the word or phrase denoting the object follows the verb. "A prudent man restrains his passions:" in this case "a prudent man," is the subject; "restrains" the attribute; "his passions" the object.

5. Syntax consists, (1.) Of *concord*, which is the agreement of one word with another, in gender, case, and number. (2.) Of *government*, which is the power which one part of speech has over another in directing its mood, tense, or case.

6. A verb must agree with its nominative case in number and person; as "I learn;" "thou walkest;" "the man runs."

7. Two or more nouns singular, joined together with a conjunction *copulative*, have verbs and pronouns agreeing with them in the plural; as "Cicero *and* I *are* well:" but if the conjunction be disjunctive, the verb will be singular; as "Thomas *or* John *hopes* to be at home."

8. A noun of multitude may sometimes have a verb or pronoun agreeing with it, either in the singular or plural number; as "the multitude eagerly *pursue their* pleasures;" or, "the multitude eagerly *pursues its* pleasures."

9. Pronouns must always agree with their antece-

dents, and the nouns for which they stand, in gender and number; as "The man *whom* I respect." "This is the flower *which* I admire." "The boys and girls enjoy *their* play."

10. When no nominative case comes between the relative and the verb, the relative is the nominative; as "The friends *who* walked with us."

11. When a nominative comes between the relative and the verb, the relative is governed by some other verb; as "*to whom* I owe my being;" here the relative *whom* is governed by the preposition *to*.

12. Every adjective belongs to a substantive expressed or understood; as "*Few* are really happy;" that is, *few persons*. "*This* is a beautiful plant;" that is, *this plant* is, &c.

13. The article *a* or *an* agrees with singular nouns only; but the article *the* may agree with singular or plural nouns; as "the field," "the fields."

QUESTIONS FOR EXAMINATION.

1. Of what does syntax treat?
2. What is a sentence?
3. Explain what is meant by the subject, attribute, and object.
4. Which precedes, and which follows the verb?
5. Of what does syntax consist?
6. How does a verb agree with its nominative case?
7. In what case do singular nouns require plural verbs?
8. May a noun of multitude have a verb plural?
9. Do pronouns agree with their antecedents?
10. When is the relative the nominative to the verb?
11. In what case is it not the nominative to the verb?
12. Must every adjective belong to some noun?
13. What is the difference in agreement between the indefinite article *a* or *an*, and the definite article *the*?

LESSON THE ELEVENTH.

SYNTAX CONTINUED.

1. One substantive governs another, signifying a different thing in the possessive case; as "My brother's horse."

2. Transitive verbs govern the objective case; as "The master instructs *me* or *him*." "A good cause supports *us* or *them*."

3. One verb governs another in the infinitive mood; as "I am ready *to answer* him, or her."

4. Participles govern the same cases as the verbs from which they are derived; as "His friend is weary in *admonishing him*."

5. Adverbs are for the most part placed before adjectives, after transitive or intransitive verbs, and frequently between the auxiliary and the verb; as "He spoke a *very* long time, and *was attentively heard* by all the company."

6. Two negatives destroy one another; as, "His manner is *not un*graceful;" that is, "He has a graceful manner."

7. Prepositions govern the objective case; as "He spoke well *of her*." "I ran *by her*, or *him*." "They will come *to us*."

8. Conjunctions connect the same moods and tenses of verbs, and cases of nouns and pronouns; as "The friend praised and rewarded us." "The master reproved *him*, and *me*, and *her*."

9. Conjunctions that are of a positive nature require the indicative mood; "He is wealthy, *because* he *is* temperate:" but those that imply something doubtful require the subjunctive mood; as "*If* I were to admonish him, he would not attend."

10. When the qualities of different things are compared, the latter noun or pronoun agrees with the verb, or is governed by the verb or the preposition expressed or understood; as "You walk faster than I:" that is, "than I walk." "They were more fortunate than we:" that is, "than we were." "He loved her more than me:" that is, "more than he loved me." "It is better expressed by him than her:" that is, "than by her."

QUESTIONS FOR EXAMINATION.

1. How do substantives govern one another?
2. What case do transitive verbs govern?

3. In what mood does one verb govern another?
4. What cases do participles govern?
5. How are adverbs placed?
6. What effect have negatives?
7. What cases do prepositions govern?
8. What is the use of conjunctions?
9. In what cases do conjunctions govern the indicative, and in what the subjunctive mood?
10. In comparing the qualities of different things, with what does the latter noun agree, or by what is it governed?

LOGIC.

ON THE CHARACTER AND WRITINGS OF LOCKE, AND THE UTILITY OF LOGIC.

"Laying aside prejudice, whether fashionable or unfashionable, let us consider whether Logic may be made subservient to any good purpose. Its professed end is to teach men to think, to judge, and to reason with accuracy."—*Reid's Appendix to Lord Kames's Sketch on the Principles and Progress of Reason.*

At the head of the metaphysical speculations of the eighteenth century, the great names of Locke and Leibnitz are placed with indisputable propriety. Whatever may be thought of the truth of their doctrines, or of their comparative rank in philosophical genius, it cannot be doubted that they exercised the chief influence on the opinions of the succeeding age. The spirit of every system which has since arisen is derived, directly or indirectly, from one of them. Our illustrious countryman was a native of Somersetshire; Leibnitz was a German: and the genius as well as the character of the philosophy of these two eminent men were diametrically opposite to each other. Their names are the most conspicuous in the two schools of philosophy, which, for want of better names, may be called *experimental* and *speculative*; though some of their followers have gone nearer to both extremes than their masters, while others have remained at various points in the space between them. There never were two contemporary philosophers whose genius were so dissimilar, and whose philosophical systems were so much at variance, not only in particular doctrines, but in spirit and tendency. It will be my business briefly to examine those of the former.

The character of Locke's writings cannot be well understood without considering the circumstances of the writer. Educated among the English Dissenters, during the short period of their political ascendancy, he early imbibed that deep piety and ardent spirit of liberty which actuated that body of men; and he probably imbibed also, in their schools, the disposition to metaphysical enquiries, which has every where accompanied the Calvinistic theology. Sects founded in the right of private judgment naturally tend to purify themselves from intolerance, and, in time, learn to respect in others the freedom of thought, to the exercise of which they owe their own existence. By the Independent divines, who were his instructors, he was initiated into those principles of religious liberty, which they were the first to teach and to disclose to the world. When free enquiry led him to milder dogmas, he retained the severe morality which was their honourable singularity, and which continues to distinguish their successors in those communities which have abandoned their rigorous opinions. His professional pursuits afterwards engaged him in the study of the physical sciences, at the moment when the spirit of experiment and observation was in its youthful fervour, and when a repugnance to scholastic subtleties was the ruling passion of the scientific world. At a more mature age, he was admitted into the society of great wits and ambitious politicians. During the remainder of his life, he was often a man of business, and always a man of the world, without much undisturbed leisure, and probably with that abated relish for merely abstract speculation, which is the inevitable result of converse with society and experience in affairs. But his political connexions agreeing with his early bias, made him a zealous advocate of liberty, in opinion and in government; and he gradually limited his zeal and activity to the illustration of such general principles as are the guardians of these great interests of human society. Almost all his writings, even his celebrated and immortal "Essay" itself, were occasioned and intended directly to counteract the enemies of reason and of freedom in his own age. The first letter on Toleration, the most original perhaps of his works, was composed in Holland, in a retirement where he was forced to conceal himself from the tyranny which pursued him into a foreign land; and it was published in England, in the year of the Revolution, to vindicate the Toleration Act, of which the author lamented the imperfection.

His "Treatise on Government" is composed of three parts,

of different character, and very unequal merit. The confutation of Sir Robert Filmer, with which it opens, has long lost all interest, and is now to be considered as an instance of the hard fate of a philosopher who is compelled to engage in a conflict with those ignoble antagonists, who acquire a momentary importance by the defence of pernicious falsehoods.

His "Essay on the Human Understanding" is the first considerable contribution in modern times towards the experimental philosophy of the human mind. The road was pointed out by Bacon: but before Locke there was no example in intellectual philosophy of an ample enumeration of facts, collected and arranged for the express purpose of legitimate generalization. He himself tells us, that his purpose was, "in a plain historical method, to give an account of the ways by which our understanding comes to attain those notions of things we have." In more modern phraseology, this would be called an attempt to ascertain, by observation, the most general facts relating to the origin of human knowledge. There is something in the plainness, and even homeliness, of Locke's language, which strongly indicates his very clear conception, that experience must be his sole guide; and his unwillingness, by the use of scholastic language, to imitate the example of those who make a shew of explaining facts, while in reality they only "darken council by words without knowledge." He is content to collect the laws of thought, as he would have collected those of any other object of physical knowledge, from observation alone.

Few books have contributed more to rectify prejudice—to undermine established errors—to diffuse a just mode of thinking—to excite a fearless spirit of enquiry—and yet to contain it within the boundaries which nature has prescribed to the human understanding. An amendment of the general habits of thought is, in most parts of knowledge, an object as important as even the discovery of new truths, though it is not so palpable, nor in its nature so capable of being estimated by superficial observers. In the mental and moral world, which scarcely admits of any thing which can be called discovery, the correction of the intellectual habits is probably the greatest service which can be rendered to science. In this respect the merit of Locke is unrivalled. His writings have diffused throughout the civilized world a love of civil liberty—the spirit of toleration and charity in religious differences—the disposition to reject whatever is obscure, fantastic, or hypothetical in speculation—to reduce verbal disputes to their proper value—to abandon problems which admit of no solu-

tion—to distrust whatever cannot be clearly expressed—to render theory the simple expression of facts—and to prefer those studies which most directly contribute to human happiness. If Bacon first discovered the rules by which knowledge is improved, Locke has most contributed to make mankind at large observe them. He has done most, though often by remedies of silent and almost insensible operation, to cure those mental distempers which obstructed the adoption of these rules; and thus led to that general diffusion of a healthful and vigorous understanding, which is at once the greatest of all improvements, and the instrument by which all other improvements must be accomplished. He has left to posterity the instructive example of a prudent reformer, and of a philosophy temperate as well as liberal, which spares the feelings of the good, and avoids direct hostility with obstinate and formidable prejudice. These benefits are very slightly counterbalanced by some political doctrines liable to misapplication, and by the scepticism of some of his ingenious followers: an inconvenience to which every philosophical school is exposed, which does not steadily limit its theory to a mere exposition of experience. If Locke made few discoveries, Socrates made none. Yet both did more for the improvement of the understanding, and not less for the progress of knowledge, than the authors of the most brilliant discoveries. Mr. Locke will ever be regarded as one of the greatest ornaments of the English nation; and the most distant posterity will speak of him in the language of gratitude and admiration.

"No man will say," says Dr. Reid, "that to think, to judge, and to reason with accuracy, is a matter of little importance; the only thing, therefore, that can admit of doubt is, whether it can be taught. To resolve this doubt, it may be observed, that our rational faculty is the gift of God, given to men in very different measures: some have a large portion, some a less; and when there is a remarkable defect of the natural power, it cannot be supplied by any culture. But this natural power, even where it is the strongest, may lie dead for want of the means of improvement. Many a savage may have been born with as good faculties as a Newton, a Bacon, or an Aristotle; but their talents were buried by having never been put to use, whilst those of the philosophers were cultivated to the best advantage. It may likewise be observed, that the chief means of improving our rational power is the vigorous exercise of it in various ways, and on different subjects, by which the habit is acquired of

exercising it properly. Without such exercise, and good sense also, a man who has studied logic all his life may be only a petulant wrangler, without true judgment or skill of reasoning in any science."

This was undoubtedly Locke's meaning, when, in his "Thoughts on Education," he says, "If you would have your son to reason well, let him read Chillingworth." The philosophy of mind has much enlarged, and altered, and improved the art of logic since Locke wrote:—to this improvement his writings have greatly contributed; and yet in the present day much less stress is laid upon it, and less time consumed in its study. "His counsel," therefore, to adopt the sentiments of a clever modern writer, "was judicious and seasonable: to wit, that the improvement of our reasoning power is to be expected much more from an intimate acquaintance with the authors who reason best, than from studying voluminous systems of school logic. But if he had meant that the study of logic was of no use, nor deserved any attention, he surely would not have taken the pains to make so considerable an addition to it, by his 'Essay on the Human Understanding,' and by his 'Thoughts on the Conduct of the Understanding;' nor would he have remitted his pupil to Chillingworth, the acutest logician, as well as the best reasoner of his age."

That a man may acquire the ability to think clearly and to reason justly in mathematics, and perhaps in any other science, without the aid of the principles and rules of logic, is indisputable. Good faculties, good examples, industry and assiduous exercise, may train a man to reason justly and acutely in his own profession without rules. "But whoever thinks that from this concession he may infer the inutility of logic, betrays by this inference a great want of that art: for he might as well infer, because a man may go from London to Edinburgh by the way of Paris, that, therefore, any other road is useless."

Mental philosophy can consist of nothing but facts; and it is at least as vain to inquire into the cause of thought, as into the cause of attraction. What the number and nature of the ultimate facts respecting mind may be, is a question which can only be determined by experience: and it is of the utmost importance not to allow their arbitrary multiplication, which enables some individuals to impose on us their own erroneous or uncertain speculations as the fundamental principles of human knowledge. No general criterion has hitherto been offered by which these last principles may

be distinguished from all other propositions. Perhaps a practical standard of some convenience would be, *that all reasoners should be required to admit every principle of which the denial renders reasoning impossible.* This is only to require that a man should admit in general terms those principles which he must assume in every particular argument, and which he has assumed in every argument which he has employed against their existence. It is, in other words, to require that a disputant shall not contradict himself: for every argument against the fundamental laws of thought absolutely assumes their existence in the premises, while it totally denies it in the conclusion.

The art of reasoning involved in the science of metaphysics may be fairly appreciated by the universality of the practice. Do what we will, we must philosophize, well or ill; and the minds of the ignorant swarm with insect hypotheses: they for ever generalize too soon, and too much. Objects at a distance, as seen by a mere glance, are much alike, and all colours are the same to those that are in the dark. Lessing has declared, that if the Almighty had offered truth in one hand, and the art of searching for it in the other, he would have taken the latter. This is undoubtedly very strong; and very different is the fashionable creed in our time: though it is confessed that metaphysics are good preparatory studies, as some green crops may be profitably raised, if to be ploughed into the land intended to bear more useful grain. It is allowed, too, that they may invigorate the faculties, as archers strengthen their arms by shooting into the air.

I think, however, that I shall render the young and anxious student in this most important science, an essential and acceptable service, by arranging, for his help and direction, a list of the most eminent writers, in an order the most convenient for study, and best calculated to facilitate a steady and regular progress. I place at the head of this list the immortal work which I have already briefly analyzed.

Locke's "Conduct of the Understanding."

The first book of his "Essay."

Duncan's "Logic;" not as a logic, but as a clear and elementary exposition of Locke's elementary opinions.

Hobbes's "Treatise on Human Nature."

The first nine chapters of the "Leviathan."

Hobbes's "Treatise on Liberty and Necessity."

I may observe, that Locke has borrowed from Hobbes, though he prudently did not venture to quote the latter, fore-

seeing that he should call up a host of implacable and powerful enemies.

Hartley's "Theory;" paying no attention to his hypothesis of vibrations.

The remainder of Locke's "Essay."

Collins on "Liberty and Necessity."

Dr. Clark's metaphysical works.

Reid's "Enquiry." His larger work may be looked at cursorily.

All Dugald Stewart's works; for though he is sometimes wrong in his elementary principles, he is always an instructive, elegant, and encouraging writer.

Berkeley's "Theory of Vision;" which I consider an inestimable contribution to science.

Whateley's "Logic."

Cudworth's "Immutable Morality."

Butler's "Analogy," and all his "Sermons."

Cooper's "Essay on Moral Obligation."

Hume's "Enquiry into the Principles of Morals."

Dr. Johnson's "Review of Soame Jenyns."

Mackintosh's "Dissertation;" to be read with care.

Dr. Brown's "Lectures." The ethical lectures seem to me inferior to the metaphysical, being not only wordy, but erroneous in the fundamental principle. He has misconceived Hartley's and Hume's opinions; yet the earliest parts of the work are of much value; especially his account of the origin of our notion of extension and eternal existence. This excepted, it appears to me that even his best passages are chiefly commentaries on Hartley's thoughts, though he does not seem to have read him carefully. Brown is also too declamatory, and too full of repetitions.

Mills's "Analysis of the Human Mind."

The writers here recommended often differ essentially from each other; but it frequently happens that to understand an author, it is necessary to look at his predecessors and his antagonists. In most speculations, prevalent opinions are either disputed or defended. This should never be forgotten.

I am aware, likewise, that this is the road-book of a long journey; but I believe, and have learned from my own experience, that, in such subjects, "the farthest way about, is the nearest way home." Mr. Horne Tooke is reported to have said of intellectual philosophy, that he had become better acquainted with the country through having had the good luck sometimes to lose his way.

To the ardent and excited student, it is, I am persuaded, altogether useless to add one word as to the probable advantages of such a laborious pursuit of first principles; being so well aware, as he must be, limited as is his experience, that to begin at the beginning in the sciences, as well as in matters of fact, is the nearest and safest road to the end. Even sensible men are too commonly satisfied with tracing their thoughts a little way backwards; and they are, of course, soon perplexed by a profounder adversary. In this respect, most people's minds are too like a child's garden, where the flowers are planted without the roots. It may be said of morals and of literature, as truly as of sculpture and painting, that to understand the outside of human nature, we should be well acquainted with the inside. It is well for those who can handle the anatomist's knife, as well as the artist's pencil.

LESSON THE FIRST.

INTRODUCTION.

1. Logic, or the art of reasoning, is intended to guide and assist the intellectual powers in the investigation of truth, and in the communication of it to others.

ILLUSTRATION.—Logic is not a mere explanation of scholastic and barbarous phrases; nor a set of rules to teach the art of disputation: but it traces the progress of the human understanding in the acquisition of knowledge, and thus suggests the best methods of avoiding error, and discovering truth. The object of this science, therefore, is to explain the nature of the human mind, and the proper manner of conducting its several powers, in order to attain knowledge and truth. It lays open those errors to which we are liable through inattention; and teaches us how to distinguish between truth and the appearance of it. By these means we become acquainted with the nature and the power of the understanding; see what things lie within its reach; where we may attain certainty and demonstration; and where we must be contented with probability.

2. The operations of the mind in acquiring and communicating knowledge are, "Perception," "Judgment,"

"Reasoning," and "Disposition;" and into these parts logic is divided.

3. *Perception*, or conception, is the attention which the mind gives to impressions made upon it, and the results of perception are sensations and ideas.

Example.—We can conceive of a horse, a tree; of motion, time, &c.; which will produce corresponding sensations and ideas.

4. *Judgment* is the operation of the mind by which we join two or more ideas together by an affirmation or negation. Sentences called propositions are the effect of judgment.

Example.—"This tree is high;" here are two ideas, one of a tree, and another of its height: the sentence is complete and affirmative. "That house is not large:" this is a negative proposition. Both are the effect of judgment.

5. In *reasoning*, we determine the relation between two ideas, by comparing them with a third idea, called the middle term.

Example.—If we affirm that "God will make a difference between the evil and good," it is the result of reasoning, by which we suppose that "A just being will make a difference between the good and evil;" and also, that "God is a just being."

6. The result of reasoning is an inference; and the expresssion of an act of reasoning is called a syllogism.

Ex.—A Creator is to be worshipped.
God is a Creator;
Therefore, God is to be worshipped.

Here is a syllogism: and the inference is, that "God is to be worshipped."

7. *Disposition* is the proper arranging of our ideas upon any subject, so as to assist our own and others' conception and memory. The result of disposition is method.

QUESTIONS FOR EXAMINATION.

1. For what is logic intended?
Can you give the illustration?

2. What are the operations of the mind with regard to logic?
3. What is meant by perception?
Give the example.
4. What do you mean by judgment, and of what are sentences the effect?
Explain what is meant by the examples.
5. What is meant by reasoning?
Explain this by means of the example.
6. What is the result and expression of reasoning?
Give the example.
7. What is disposition, and the result of it?

LESSON THE SECOND.

OF IDEAS.

1. There are two modes of perception, viz., sensation and reflection.

2. *Sensation* is the perception of an object by the organs of sense; which are five, namely, the "sight," "hearing," "taste," "smell," and "touch."

ILLUSTRATION.—It is by our senses we acquire the ideas of light and darkness; of heat and cold; and all those other impressions which we term sensible qualities. It is so difficult to unravel the operations of the human understanding, and to reduce them to their first principles, that we cannot expect to succeed in the attempt, but by beginning with the simplest, and proceeding by very cautious steps to the more complex. The five external senses may, for this reason, claim to be the first considered in an analysis of the human faculties.

3. *Reflection* is the mind's perception of its own faculties and operations, and by this we acquire sensations and ideas.

ILLUSTRATION.—Reflection pre-supposes sensation, as the impressions it furnishes are only the effect of the varions powers of the understanding, employed about perceptions already in the mind.

4. A *sensation* is the impression made upon the mind by an object actually present; an *idea* is a revived impression in the absence of the object.

ILLUSTRATION.—The grand source and inlet of knowledge is sensation, which comprehends all the notices conveyed into the mind by impulses made upon the organs of sense.

5. Ideas are either simple or complex.

6. *Simple ideas* are those that exist in the mind under one uniform appearance, without variety or composition: as a colour, or sound.

7. *Complex ideas* are those that may be divided into two or more simple ideas: as a square, a triangle, &c.

8. Simple ideas enter the mind only by inlets appropriated to this purpose, and it cannot refuse to receive them.

9. Simple ideas are incapable of change, but they gradually wear out of the mind unless revived by the same means by which they were originally acquired.

Ex.—We soon forget the countenance of a man whom we have seen but once.

10. Simple ideas are capable of combinations in an indefinite variety of forms, and are the materials of all our knowledge.

11. Complex ideas are either representations of objects really existing, or collections made at the pleasure of the mind.

12. The objects really existing are either substances, or modes.

13. *Substances* are beings or things subsisting by themselves: as steel, brass, &c. *Modes* are the properties of substances, and dependant upon them for support: as hardness, softness, brightness, extension, &c.

14. Our ideas of substances extend only to their properties.

15. Modes are either *essential* or *accidental:* an essential mode is that which is necessary to its existence: as *solidity* and *roundness* are essential to a bowl: an accidental mode is that which is not necessary to the existence of the subject: as roundness is only an accidental mode of a stone: the bowl cannot exist, as a bowl, without roundness, but a stone may.

QUESTIONS FOR EXAMINATION.

1. How many modes of perception are there?
2. What is meant by sensation; and which are the senses? Give the illustration.
3. What do you mean by reflection? What does it pre-suppose?
4. What do you mean by a sensation, and also by an idea? Give the illustration.
5. How are ideas divided?
6. What are simple ideas?
7. What are complex ideas?
8. How do simple ideas enter the mind?
9. Do simple ideas change, or wear out? What is the example?
10. Can simple ideas be combined, and how are they important?
11. In what manner do complex ideas exist in the mind?
12. Into what are existing objects divided?
13. What do you mean by substances and modes?
14. To what do our ideas of substances extend?
15. How are modes distinguished, and how are they defined?

LESSON THE THIRD.

OF IDEAS AND WORDS.

1. Complex ideas, consisting of collections formed at the pleasure of the mind, are produced by "composition," "abstraction," and "comparison."

2. *Composition* is the joining together two or more simple ideas, and considering them as one picture or representation: such is a waggon, a mile-stone, &c.

ILLUSTRATION.—By adding units together we come to the combinations of dozen, score, hundred, &c. Again, harmony is a compound idea made by the union of many sounds.

3. *Abstraction* is the attention of the mind to those properties in an object which it possesses in common with others, while it overlooks those which are peculiar to it.

Ex.—In contemplating a square, triangle, circle, &c.,

we retain only a notion of their figure, without regard to their size.

4. *Comparison* is the act of the mind by which two or more objects being brought at once into the view of the mind, their mutual correspondences or relations are discovered. Hence the ideas of greater and less; father and child; &c.

5. Words are articulate sounds used as the signs of ideas.

6. The connection between words and ideas is perfectly arbitrary; but, by frequent use, a term becomes so strongly associated with an idea, that it never fails to suggest it.

7. The use of words is to record our own trains of ideas, and to communicate our thoughts to others; our ideas are recorded by being clothed in words, and communicated in writing.

8. We communicate our thoughts to one another by a tacit agreement to annex the same ideas to the same words.

9. Language may be resolved into nouns and verbs, with their abbreviations.

10. Nouns express the names of things, and are either substantives, which are the things spoken of, or adjectives, which denote the qualities or circumstances belonging to them.

11. Verbs express *modes* of existence, either simply, as "to be:" or existence in an active state, as "to run," "to walk," &c.: or existence in a passive state, as "to be elected."

12. Indeclinable particles are abbreviations of nouns and verbs, invented for the greater expedition of communicating our thoughts: thus *if* signifies *give: and* signifies *add*, being the imperatives of the verbs.

13. Simple words are the elements of language as simple ideas are of all knowledge.

QUESTIONS FOR EXAMINATION.

1. How are complex ideas, consisting of collections formed at pleasure, produced?

2. What is meant by composition?
Give the illustration.
3. What is meant by abstraction?
4. What is meant by comparison?
5. What are words?
6. How are words and ideas connected?
7. What is the use of words?
8. By what supposed agreement are we enabled to communicate our thoughts to one another?
9. Into what is language resolved?
10. What is meant by nouns?
11. What do verbs express?
12. What are indeclinable particles?
13. What are simple words?

LESSON THE FOURTH.

OF DEFINITION.

1. Definition is an enumeration of the chief simple ideas of which a compound idea consists, in order to ascertain or explain its nature and character.

2. Definitions are either nominal, of the name; or real, of the thing.

3. A *nominal* definition is an enumeration of certain marks or characters, sufficient to distinguish the thing defined from any other. Such is the definition of a square, as a figure containing four equal sides, and four right angles.

4. A definition of a *thing* includes an enumeration of the principal attributes of the thing, in order to explain its nature: thus an isosceles triangle is a figure having the angles at the base equal.

5. Definitions are either *accurate* or *inaccurate;* the first are strictly definitions: the second only descriptions.

6. The rules for a good definition are, (1.) It should be clear, and more obvious, than the thing defined. (2.) It should agree to all the species included under the same idea. (3.) It must be peculiar to the thing defined. (4.) It should be short. (5.) Neither the thing defined

nor a mere synonymous name should make any part of the definition.

QUESTIONS FOR EXAMINATION.

1. What is a definition?
2. How are definitions distinguished?
3. What do you mean by a *nominal* definition?
4. What is meant by the definition of a *thing*?
5. How are definitions distinguished with regard to accuracy?
6. What are the rules for a good definition?

LESSON THE FIFTH.

OF JUDGMENT, TESTIMONY, AND PROPOSITIONS.

1. When two ideas are compared, they either *concur*, as snow and whiteness; or they *coincide*, as God and Creator: or they do not concur, as vice and usefulness; or they do not coincide, as man and brute.

2. When the concurrence or coincidence of ideas or the want of it is perceived by the intervention of a third idea, this is called *judgment*.

3. The sources of judgment are consciousness, sense, intuition, and testimony.

4. *Consciousness* is the mind's perception of its own existence, faculties, and operations.

5. The senses teach us the existence, properties, and powers of external objects. and the foundations of natural knowledge.

6. *Intuition* is the instant perception of the relation between two ideas; as "the whole is greater than any of its parts, and equal to all its parts."

7. *Testimony* is the criterion of facts, which do not fall immediately under our own observation.

ILLUSTRATION.—The province of testimony is the proof of facts, which, having happened in past times, or in distant places, have not fallen under the cognizance of the senses. Testimony must be true when the relater is not himself deceived, and does not intend to impose on others.

8. A judgment or mental proposition, is that union or separation of the ideas which is the result of the act of judging, and it may exist without any connection with words.

9. A proposition is a judgment clothed in words; and it consists of three parts: the subject, the predicate, and copula.

Ex.—1. Virtue is excellent.

2. Gold and silver are the most precious metals.

Here *virtue* in the one example, and *gold and silver* in the other, are subjects: the verbs *is* and *are* the copulæ; *excellent* and *most precious metals* the predicates.

10. The *subject* of a proposition is the idea concerning which something is affirmed or denied: the *predicate* is the idea united to, or separated from, the subject: the *copula* is the sign which represents the union or the separation of the subject of the predicate.

Illustration.—In the proposition, "Wisdom is the principal thing." *Wisdom* is the subject, *is* the copula, and *principal thing* the predicate.

11. The several parts of a proposition are not always distinctly expressed, but are always understood: thus "I walk," "he pleads," may be resolved into "I am walking," "he is pleading."

12. Propositions may be divided into affirmative and negative: the *affirmative* connects the predicate with the subject: as "gold is heavy:" the *negative* separates the predicate from the subject: as "Man is not perfect."

13. Propositions are universal and particular: in an *universal* proposition the predicate extends to the whole subject: as "*All men* are mortal." "*No man* is truly happy."

14. The signs of an universal proposition are usually the words *all*, *every*, *no*, *none*.

15. In a *particular* proposition the predicate is limited to a part of the subject: as "*Some* people are good." "*Many* philosophers have been deceived."

16. The signs of particular propositions are *some*, *many*, *few*, &c.

17. Propositions are true or false: a *true* proposition unites ideas that agree, and separates those that disagree: as "God is good." "Men are not truly wise."

18. A *false* proposition affirms an agreement between ideas that disagree, and a disagreement between those which agree: as "A good king oppresses his subjects." "Virtue is not the road to solid happiness."

19. A demonstrable proposition is one that may be proved by a train of reasoning, called demonstration: as "Any two angles of a triangle, taken together, are greater than the third.

ILLUSTRATION.—Demonstration is a succession of connected propositions, beginning with self-evident, and advancing to remoter truths: such is mathematical demonstration which begins with definitions; from these it advances to axioms, or self-evident propositions; and thence to more remote truths.

20. Corollaries are inferences deduced from truths already demonstrated.

QUESTIONS FOR EXAMINATION.

1. What are the results of the comparison of ideas?
2. What is meant by judgment?
3. What are the sources of judgment?
4. How is consciousness defined?
5. What do the senses teach?
6. What is intuition?
7. What is meant by testimony?

Give the illustration.

8. What is meant by a judgment, or mental proposition?
9. What is a proposition?

Explain this by examples.

10. What is meant by the "subject," "predicate," and "copula?"
11. Are the several parts of a proposition always distinctly expressed?
12. How are propositions divided, and what do each mean?
13. What is the next division, and what is meant by an universal proposition?

14. What are the signs of an universal proposition?
15. How is a particular proposition defined?
16. Which are the signs of a particular proposition?
17. How are propositions divided as to their truth, and what is meant by a true proposition?
18. Explain what is meant by a false proposition.
19. What is a demonstrable proposition?
Give the illustration.
20. What are corollaries?

LESSON THE SIXTH.

OF REASONING.

1. Reasoning determines the relation between two ideas, by the intervention of a third with which they are compared.

ILLUSTRATION.—When, for instance, we compare two figures of a different make in order to judge of their equality or inequality, it is plain, that, by barely considering the figures themselves, we cannot arrive at an exact determination; because, by reason of their disagreeing forms, it is impossible to put them together, so that their several parts shall mutually coincide.* Here, then, it becomes necessary to look out for some third idea that will admit of such an application as the present case requires; wherein if we succeed, all difficulties vanish, and the relation we are in quest of may be traced with ease. Thus right-lined figures are all reduced to squares, by means of which we can measure their areas, and determine exactly their agreement or disagreement in point of magnitude. The manner of determining the relation between any two ideas, by the intervention of some third with which they may be compared, is that which we call *reasoning:* and is, indeed, the chief instrument by which we push our discoveries, and enlarge our knowledge. The great art lies in finding out such intermediate ideas, as, when compared with the others in the question, will furnish evident and known truths; because, as will afterwards appear, it is only by means of them

that we arrive at the knowledge of what is hidden and remote.

2. If the two given ideas agree with the third idea, it is evident that they must agree with each other. If one agrees and the other disagrees, their mutual disagreement is inferred.

3. Every act of reasoning consists of three judgments, in two of which the given ideas are compared with the third idea, and in the last they are joined to, or separated from, each other.

4. A syllogism is the expression of an act of reasoning, and includes three distinct propositions.

5. The intermediate idea made use of to discover the agreement or disagreement we are in search of, is called the middle term, and the two ideas with which this third is compared, are called extremes.

Ex.—1. Suppose a comparison to be made between industry and honour; and utility be the third idea: then the syllogism will stand,

Whatever is useful is honourable.
Industry is useful;
Therefore industry is honourable.

Ex.—2. If the inquiry be, whether a man is bound to cultivate his mind: I say,

Every creature possessed of reason is bound to cultivate his mind.
Man is possessed of reason;
Therefore man is bound to cultivate his mind.

6. In syllogisms the proposition containing the inference is called the *conclusion;* the two preceding positions are the *premises.*

7. Of the two premises, that is called the *major proposition* in which the greater extreme is compared with the middle term: the *minor proposition* is that in which the less extreme is compared with it.

Ex.—In the syllogism,

Truth is venerable.
Christianity is truth;
Therefore Christianity is venerable.

"Christianity," "Venerable," and "Truth" are the three terms of the syllogism. "Christianity" and "Venerable" are the extremes, and "Truth" is the middle term. "Venerable" is the *major*, and "Christianity" the *minor term.* "Truth is venerable;" "Christianity is truth;" are the *premises:* "therefore Christianity is venerable," is the conclusion. "Truth is venerable," is the *major proposition;* "Christianity is truth," is the *minor proposition.*

[Syllogisms may be almost indefinitely varied, and each variety has obtained a distinct name; in this place a very few will be noticed.]

8. *Hypothetical* syllogisms are those in which the major premise is an hypothetical proposition.

Ex.—If there be a God he ought to be worshipped.
But there is a God;
Therefore he ought to be worshipped.

9. A *dilemma* is a syllogism in which the consequent of the major is a disjunctive proposition, which is taken away in the minor: or it is an argument by which we endeavour to prove the absurdity or falsehood of some assertion.

Ex.—If God did not create the world perfect in its kind, it must have been from want of inclination or power.
But it could not have been from want of inclination or want of power;
Therefore he created the world perfect in its kind.

10. *Analogy* is an argument from proportionable causes to proportionable effects; and from similarity of circumstances to similarity of consequences.

Ex.—All matter with which we are acquainted gravitates;
Therefore gravitation is an universal property of matter.

Illustration.—By this mode of argument, we infer that the sun will rise to-morrow, and the next day, and so on. Thus the philosopher believes that the planets are inhabited: and the man of business regards it as

certain that a dishonest and avaricious man will take an undue advantage in trade, where the opportunity occurs, as that fire will burn, or a ball will run down a hill. In other cases the argument cannot be much depended on, as when we attempt to draw conclusions concerning the conduct of voluntary agents; this is owing to the difficulty which one person has to enter into the views, objects, and feelings of another, and consequently to foresee, in given circumstances, how another man will act.

QUESTIONS FOR EXAMINATION.

1. What does the act of reasoning determine?

Illustrate the intervention of a third idea.

2. In what case will two given ideas be found to agree with one another?

3. Of what does every act of reasoning consist?

4. What is a syllogism?

5. What is meant by the middle term?

What are the two examples?

6. What is meant by the conclusion and premises?

7. What is meant by the major and minor proposition?

Explain the several terms by the example.

8. What do you mean by hypothetical syllogisms?

Explain the principle by example.

9. What is meant by a dilemma?

Give the example.

10. What is the nature of the argument from analogy?

Give the example.

Show by the illustration in what cases the argument is and is not very strong.

LESSON THE SEVENTH.

OF SOPHISMS, DISPOSITION AND METHOD, AND THE SOURCES OF ERROR.

1. A sophism is a false syllogism not obviously apparent. Sophisms are as follow:—

2. "A mistake of the question;" that is, when a proposition is proved which has no necessary connexion with the question: this is called "ignorantio elenchi:" as if unbelievers argue that Christianity is not true, because "transubstantiation is incredible:" here is a mis-

take of the question, by taking a corruption, of Christianity for Christianity itself.

3. "Petitio principii;" or "begging the question," is taking for granted what ought to be proved.

4. "Arguing in a circle," is to prove the premises by the conclusion, and the conclusion by the premises.

5. *Disposition*, in logic, is the arranging ideas so as to facilitate the recollection, the improvement, or the communication of knowledge.

6. Method is the effect of disposition: it is the actual arrangement of ideas in the mind; and is either analytic or synthetic.

7. Method by analysis resolves a complex idea into its component principles.

8. Method by synthesis begins with simple and self-evident principles, and advances gradually to remote and complex propositions.

ILLUSTRATION.—If I take a watch to pieces in order to understand its structure, I gain my knowledge by analysis; but if I acquire the same information by looking at the artist putting the parts together, I learn by synthesis. By analysis we learn, in experimental philosophy and chemistry, the parts of compound bodies. By synthesis we study the science of geometry.

9. The sources of error are, (1.) the want of diligence in investigation. (2.) Judging of things by their external appearances only. (3.) Comparing things with our own situation in life, or as they happen to affect us. (4.) The associating an idea with something disagreeable, or the contrary. (5.) Prejudices formed in our infancy. (6.) Giving credit to the assertions of others, without inquiring into their motives; and (7.) the force and influence of custom and fashion.—See Watts's Logic.

QUESTIONS FOR EXAMINATION.

1. What is a sophism?

2. What is meant by the sophism usually termed "ignorantio elenchi?"

3. What is meant by the "petitio principii?"

4. What do you mean by arguing in a circle?

5. What is disposition in logic?
6. What is method, and how many kinds of method are there?
7. What is meant by the analytic method?
8. What is meant by the synthetic method?
Explain the two methods by examples.
9. What are the chief sources of error in judging and arguing?

LESSON THE EIGHTH.

OF TOPICS, PROPOSITIONS, DEMONSTRATIONS, AND DIFFERENT KINDS OF ARGUMENT.

1. Topics, or common-places, ,are general subjects from whence arguments are drawn, such as history, philosophy, morals, &c.

2. The proof of a proposition is a syllogism, or a series of syllogisms collecting that proposition from known truths.

3. Where the syllogisms depend wholly on definitions, intuitive truths, and propositions already established, the argument is called a mathematical demonstration.

4. Demonstrations are of two kinds, viz., those *a priori* and *a posteriori*.

5. Demonstrations *a priori*, argue from the cause to the effect: thus the future happiness of man is proved from the infinite goodness of God.

Ex.—God is infinite in power, wisdom, and benevolence:
Therefore, the universe that he made is unlimited in extent, duration, and felicity.

6. Demonstrations *a posteriori* argue from the effect to the cause: thus the wisdom and the power of God are proved from the variety, unity, and excellence of his works.

Ex.—The universe abounds in marks of excellent contrivance and design:
Therefore, there is an intelligent and benevolent first cause of all.

7. A direct argument is that which immediately proves the proposition in question.

8. An indirect argument proves the conclusion, by

proving or disproving some proposition upon which the conclusion depends.

9. "Reductio ad absurdum," proves the conclusion, by demonstrating the absurdity of the contradictory proposition.

10. "Argumentum a fortiori," proves the conclusion, by proving a less probable proposition on which the conclusion depends.

11. "Argumentum ad judicium," is an appeal to the common sense of mankind.

12. "Argumentum ad fidem," is founded upon testimony either human or divine.

13. "Argumentum ad ignorantiam," is founded upon insufficient principles, which the opponent has not skill to refute.

14. "Argumentum ad hominem," an appeal to a man's professed principles.

15. "Argumentum ad verecundiam," is drawn from authority we are ashamed to dispute.

16. "Argumentum ad passiones," is an address to the passions of the hearers.

QUESTIONS FOR EXAMINATION.

1. What do you mean by topics?
2. What is meant by the proof of a proposition?
3. What is arithmetical demonstration?
4. How many kinds of demonstrations are there?
5. What is meant by demonstrations *a priori*? Give the example.
6. What is meant by demonstrations *a posteriori*? Give the example.
7. What is meant by a direct argument?
8. What is meant by an indirect argument?
9. What is the nature of the argument "reductio ad absurdum?"
10. What is the argument "a fortiori?"
11. What is the argument "ad judicium?"
12. What is the argument "ad fidem?"
13. What is the argument "ad ignorantium?"
14. What is the argument "ad hominem?"
15. What is the argument "ad verecundiam?"
16. What is the argument "ad passiones?"

RHETORIC.

THE NATURE AND UTILITY OF ELOQUENCE.

"Eloquence is the power of speaking with fluency and elegance."
Dr. Johnson's Dictionary.

"Eloquence is the art of speaking or writing well, so as to move and persuade."—*Chambers's Cyclopædia.*

GENERALLY prevalent as the study of natural philosophy is at present in this kingdom, and particularly cultivated as this science has been by the most eminent and influential men of the age, it would be somewhat surprising if the philosophy of the fine arts were held in a just and proportionate estimation. Without incurring the suspicion of thinking disrespectfully of other pursuits, I may be permitted to say, that the study of that grand and seducing science, natural philosophy, has a tendency to excite in its followers low ideas of arts as useful as any that can be founded even upon its noblest discoveries. It is true, that in distinguishing the arts from each other, the fine arts have been usually opposed to the useful. But is not this improper? and would it not be better, as well as more just, to consider them as divided into the liberal and the mechanical? Had I thought eloquence to be a fine art only, in the common sense of that term, I should have probably saved myself the trouble of thinking or writing about it at all. But I think otherwise: eloquence, so far as it is an art, is undoubtedly classed with propriety among the fine arts; since the means it uses to effect its purposes are not mechanical, and inasmuch as it is so constantly connected with the strongest exercises of the imagination. But surely it can never be excluded from an eminent place among the useful arts, so long as men have prejudices to be attacked, fears to be allayed, hopes to be excited, or passions to be moved; and so long, it may be added, as they have understandings to be informed. For perhaps the most extensive field for the display of real ability in speaking is, the rich, the vast, and hitherto imperfectly cultivated tract of *probable evidence.*

Within the sphere of demonstration, indeed, eloquence has but little to do, having only room enough to exhibit two of

her lowest qualities, perspicuity and order; but demonstration, though absolute as far as her power extends, reigns over a very narrow territory. I will not presume to go so far as some have done in their eulogiums upon eloquence, but I will say, that that art which teaches us how we are likely, in the most effectual manner, to make ourselves masters of other mens' minds by speech, must be permitted to rank very highly in the scale of useful studies.

It has, in truth, been common with those men of sense who have themselves been deficient in expression, to speak with contempt of the eloquence of others, and to represent it as useless, at least, if not highly dangerous; nay, some men have very dexterously used the very art itself to decry its importance, and to vilify its tendency. "It is evident," says Mr. Locke, "how men love to deceive, and be deceived; since rhetoric, that powerful instrument of error and deceit, has its established professors, is publicly taught, and has always been had in great reputation."* "What is the end of eloquence," says the acute and eloquent Warburton, "but to stifle reason and inflame the passions?"† The prejudices of Mr. Locke were undoubtedly honest, but they plainly shew that he mistook the abuse of the art for the art itself; and, happily for mankind, Bacon's observation is true:—"No man can well speak fair of things sordid and base, but in things honest it is an easy matter to be eloquent." To the Bishop's authority it may be objected, as Thucydides says it was to Cleon's, "that because he used to hold the bad side in the causes he pleaded, therefore he was ever inveighing against eloquence and good speech." It were easy to multiply the examples of such misrepresentations; the sophists and the fathers of old, the metaphysicians and theologians of late, have united in abusing an art which they wanted judgment, as well as taste, to understand. Yet, in all the various instances of these inconsiderate attacks, it ever appeared to me, that the objections and censures constantly arose from a misconception of the real nature of the art.

"It is poor eloquence," says Sir Joshua Reynolds, "that only shews a man can talk."

And this species of eloquence, it must be confessed, abounds in the present day. There are but few public speakers who give any attention to their art, excepting those who debase it by the ornaments of a most vicious taste. Not, indeed, that the two defects are often kept apart; for some men appear

* "Essay on Human Understanding," Book III. ch. 10.

† Warburton's "Doctrine of Grace," ch. 9.

to bestow but little pains upon the preparation of the vilest composition that ever offended a classical ear, although it displays an endless variety of far-fetched thoughts, forced metaphors, unnatural expressions, and violent perversions of ordinary language: in a word, it is worthless, without the poor merit of being elaborate; and affords a new instance how wide a departure may be made from nature with very little care, and how apt easy writing is to prove hard reading.

Among the sources of this corruption may clearly be distinguished as the most fruitful, the habit of extempore speaking acquired rapidly by persons who frequent popular assemblies; and, beginning at the wrong end, attempt to speak before they have studied the art of oratory, or even duly stored their minds with the treasures of thought and of language, which can only be drawn from assiduous intercourse with the ancient and modern classics. The truth is, that a certain proficiency in public speaking may be attained with nearly infallible certainty, by any person who chooses to give himself the trouble of frequently trying it, and can harden himself against the pain of frequent failures. Complete self-possession and perfect fluency are thus acquired, almost mechanically, and with little or no reference to the talents of him who becomes possessed of them. If he is a man of no capacity, his speeches will, of course, be very bad; but, though he be a man of genius, they will not be eloquent. A sensible remark, or a fine image, may frequently occur; but the loose, and slovenly, and poor diction, the want of art in combining and disposing his ideas, the inability to bring out many of his thoughts, and the utter incompetency to present any of them in the best and most efficient form, will deprive such a speaker of all claims to the character of an orator, and reduce him to the level of an ordinary talker. The same man, had he never spoken in public, would have possessed the same powers of convincing or expounding, provided he were only called upon to exert them in conversation with one or two persons Perhaps the habit of speaking may have taught him something of arrangement, and a few of the simplest methods of producing an impression; but beyond these first steps he cannot possibly proceed by this empirical process; and his diction is sure to be much worse than if he had never made the attempt: clumsy, redundant, incorrect, unlimited in quantity, but of no value. Such a speaker is never in want of a word, and hardly ever has one that is worth having.

It is a very common error to call this natural eloquence; it is the reverse: it is neither natural nor eloquent. A per-

son under the influence of strong passions or feelings, and pouring forth all that fills his mind, produces a powerful effect on his hearers, and frequently attains, without any art, the highest beauties of rhetoric. The language of the passions flows easily; but it is concise and simple, and the opposite of that wordiness which I have been describing. The untaught speaker, who is also unpractised, and utters according to the dictates of his feelings, now and then succeeds perfectly; but in those instances, he would not be the less successful for having studied the art; while that study would enable him to succeed equally in all that he delivers, and give him the same controul over the feelings of others, whatever might be the state of his own.

Now I cannot imagine any better corrective to the faults of which I am complaining in the eloquence of modern times, than the habitual contemplation of those exquisite models which the ancients have left us—the chaste beauties of classic Greek and Latin composition. Their perfect success, both in moving the audience to whom they were addressed and the readers in all ages who studied them, cannot be denied: their superiority to all that has been produced in other countries is confessed. There may be—there must be—therefore, some use in observing how certainly they were the result of intense labour; labour previously bestowed to acquire the power, and the utmost care used in almost every exercise of that power. Without somewhat both of this discipline and this sedulous attention, it would be as vain to think of emulating those divine originals, by dint of a habit of fluent speech attained through much careless practice, as to attempt painting like Raphael, without having learned to to draw, and by the help of some mechanical contrivance.

It cannot but have been matter of surprise to such as are conversant with the works of the most celebrated rhetoricians, that they should differ so generally and so widely respecting the nature of the art which they profess to teach. In the fifteenth chapter of his second book, Quintilian states and refutes a great variety of different definitions, which, even in his time, had been given of rhetoric; and he censures among others, those that rested on the authority of names no less eminent than Isocrates, Plato, Aristotle, and Cicero. He then proceeds to express and support his own opinion; but less skilfully, and less successfully, than he had attacked the sentiments of his predecessors. The same irreconcileable variety of opinion prevails among later writers on this subject; which, to say the truth, has been considered by so

many able authors, and by some of such exalted reputation, that the mention which I make of this difference among them may serve as my apology for presuming to go over the ground which such men have trodden. Since all cannot be right where all disagree, the authority of one serves to counterbalance that of another; and thus a man may be allowed to differ from any of them, without dreading the imputation of vanity.

Perhaps the most sensible, most substantial, and most useful idea of eloquence, is that expressed by Dr. Campbell, in the first sentence of his "Philosophy of Rhetoric:"—"Eloquence is that art, or talent, by which a discourse is adapted to its end." "Whatever composition," said the celebrated Mr. Wilkes, in one of his speeches, "produces the effect which is intended, in the most forcible manner, is, in my opinion, the best, and most to be approved. That mode should always be pursued: it has the most merit, as well as the most success, on the great theatre of the world, no less than on the stage, whether you mean to inspire pity, terror, or any other passion." It may perhaps be objected, that the word eloquence has generally been used in a more limited sense; and, to say the truth, it has by many been applied to denote ornamental composition only. But has not this arisen from a mistake, by which a part of the art has been mistaken for the whole? This has been the case with poetry; and it is amusing to observe the difficulties into which the error has brought many learned men, in their attempts to settle the nature and essential qualities of this noble art. Some have thought its nature to consist in imagery, some in imitation, some in fiction, some in metre, and others in passion; whereas these are only so many different means employed by the poet to effect his purposes, and are all mere parts of that of which it has been supposed they constitute the essence. However, let the common meaning of the term be what it may, we are not now considering the acceptation of a word, but the real nature of a serious art. The existence of such an art can hardly be doubted, for that would be to question whether men speak by accident or design, when they take no thought, or when they previously consider what they are about to do. Nature, it must be confessed, does much, and will not only lead, but compel us, on interesting occasions, to use those forms of speech (even the most complex) which rhetoricians have arranged and named. Perhaps no language is more natural than that which abounds with figure and allusion. Yet still ability alone is not sufficient; and a living

man, of high rank in politics, might be pointed out, who, though gifted far beyond any of his contemporaries, and greatly superior to them in acquirements, has yet been often a useless, and sometimes a dangerous, auxiliary, because he wanted the skill to manage his prodigious powers. He is ever saying something, only for the sake of saying it, merely because it is singular, beautiful, or sublime, and without any regard to its effect on his auditors. A real thought he can never dismiss, till he has made it the subject of innumerable comparisons, or darkened it by superabundant illustration.* If it be possible for such a waste of talents to be occasioned by a deficiency in the art we are speaking of, it may not be amiss to consider whether the definition given of it by Dr. Campbell be the true one, and at the same time to examine the opinions of the other celebrated writers to whose definitions I have alluded, as they are maintained and defended by two authors of great reputation, and of peculiar abilities for the discussion of such a subject, Dr. Browne, and Dr. Leland, both of whom have stated their sentiments at length; the former in his "Essay on Ridicule," and the latter in his "Dissertation on the Principles of Human Eloquence."

Dr. Browne speaks thus:—"As eloquence is of a vague, unsteady nature, merely relative to the imagination and the passions of mankind, so there must be several orders and degrees of it, subordinate to each other in dignity, yet each perfect in its kind. The common *end* of each is *persuasion*: the means are different, according to the various capacities, fancies, and affections of those whom the artist attempts to persuade. The pathetic orator, who throws a congregation of enthusiasts into tears and groans, would raise affections of a very different nature should he attempt to proselyte an English Parliament. As, on the other hand, the finest speaker that ever commanded the house would in vain point the thunder of his eloquence on a Quaker meeting.—"Essay on Ridicule," sect. 3, p. 32.

Of this passage, Dr. Leland says, "This is plausibly and ingeniously urged; but the whole argument is founded on the supposition that eloquence and persuasion are one and the same, and that to be denominated an orator, no more is necessary than to influence and move the hearer: a supposition which cannot be admitted, however witty men may have

* The reader will have no difficulty in recognizing the individual here alluded to, although he may find obstacles beyond the strength of his candour to overcome, in pardoning the freedom of animadversion upon so resplendent a mind and a genius as that of Lord BROUGHAM!!

talked of the 'eloquence of silence,' or the 'eloquence of nonsense.' The alluring accents of an harlot move the sensualist; the abject and extravagant praises of a flatterer move the vain; and the plain promise of a large reward, expressed without trope or figure, may have the greatest power over the conduct of a traitor or an assassin. But it will by no means follow that the harlot, the flatterer, or the suborner is *eloquent.* To merit this praise, a man must persuade (if he does persuade) by the real excellencies, the engaging and conciliating qualities, of speech. So that the Doctor's orator who throws a congregation of enthusiasts into tears and groans, is, in reality, no orator at all; because he owes his influence not to clearness and strength of reasoning—not to dignity of sentiment, force or eloquence of expression, and the like—but to senseless exclamation, unmeaning rhapsody; or to grimace, to a sigh, to a rueful countenance; and if he would in vain endeavour to proselyte an English Parliament, it is for this reason that he is no orator: nor can any man, without any one of the *opposita,* the rational excellencies and engaging qualities of speech, be said to possess a degree of eloquence perfect in its kind."—Leland's "Dissertation," ch. 14.

What Leland says of Browne's may as justly be said of his own argument, that it is plausibly and ingeniously urged; but probably the opinion of neither is true. Although it may be acknowledged that "eloquence is relative to the imagination and passions of men," yet it does not therefore follow that it is "of a vague, unsteady nature." It might as justly be said that the art of music is of a vague, unsteady nature, because it produces compositions so infinitely various; or that the art of the painter is liable to the same reflection, because it is sometimes exercised on copper, and sometimes on canvass. The arts themselves are fixed, steady, and immutable; it is only the objects on which they operate that are various and perishable. Neither is it true that the *only end* of all eloquence is persuasion. An orator often undoubtedly aims to persuade, but he generally has some other end in view. He frequently wishes to alarm, to arouse, to depress, to excite our pity, or to fire our indignation, and sometimes is only desirous to delight the imagination. Now these different objects can never be reduced under the general head of persuasion, without departing most unwarrantably from the common acceptation of that term. The ingenious instances adduced in the last sentence of the quotation from Browne, are certainly not sufficient to prove either of his

positions: namely, that eloquence is of a "vague, unsteady nature," or that the "common end of all eloquent discourse is persuasion." The answer just given to the principles themselves, will also destroy the application of these instances. And, in truth, the facts which he takes notice of may be accounted for in a much more reasonable and unobjectionable manner.

That the fanatic preacher, or the equally wild and illiterate political orator of public meetings, hustings, and tavern assemblies, would produce no other effect in parliament but that of making himself ridiculous, is unquestionable;* and why? Because, in attempting to affect the house by the use of the same means as those that are successful in his own pulpit, or upon his own rostrum, he would cease to be eloquent. He would be violating one of the fundamental rules of rhetoric, which teaches us that the speaker ought to have a constant regard to the *quality* of his audience. His ill success would therefore be owing to his want of art. He would fail because he was ineloquent. The eloquence which he had displayed on his own ground would still be unimpeachable.

The same reasoning is just as applicable to the parliamentary speaker, who should point the thunder of his eloquence on a Quaker meeting. The thundering sort of eloquence would be here misapplied; and how many soever he might use of those conciliating qualities of speech which Leland speaks of, he would still be unsuccessful, because his speech would not be *ad homines*. Dr. Leland's remarks are truly sensible, and would not be liable to objection, if altered but a little. The addition to be recommended is a short explanation of what he means by those rational and real excellencies, those conciliating qualities of speech, which he repeats as the basis of his reasoning. Had he been called upon for such an explanation, he would, I am persuaded, have expressed himself so as to deviate materially from the truth of the case. He would probably have said, that nature had at first suggested certain forms of speech, which rhetoricians had arranged and settled; and that these he meant to describe by the terms rational and real excellencies, engaging and conciliating qualities. This, others *have* said; and to such let it be answered, that perhaps the most common faults of all bad writing arise from the supposition of something intrinsically excellent and eloquent in certain forms of speech, even when considered without any view to the effects which

* The proceedings of the House of Commons will supply facts to elucidate this reasoning, should the reader ask for them.

they are fitted to produce. Most writers, it must be confessed, employ tropes and figures, because they *are* tropes and figures, and not because they are calculated to produce certain effects on the minds of their readers or hearers. The term conciliating is itself relative, and supposes somebody to be conciliated; and these conciliating qualities of speech must vary as much as the tempers and understandings of those who are to be conciliated.

Instead, therefore, of concluding, with Dr. Browne, that eloquence is of a vague, unsteady nature, or with Leland, that the enthusiast would fail because he is no orator, let these inferences be drawn—that eloquence is fixed on steady and unchangeable principles; that it is exceedingly extensive in its use, and relates to every kind of discourse or speech that can be imagined; that he who follows its precepts in one instance, is in that instance truly eloquent, however he may fail of success when attempting another kind of speaking, whether it be of a higher or lower degree; and, in short, let Dr. Campbell's definition be thought the true one, when he says that "eloquence is the art by which a discourse is adapted to its end." This definition solves all difficulties, explains and, as it were, embodies all rules, and is the grand axiom by which the propriety of every subordinate rhetorical precept must be finally tried. If such conclusions can be satisfactorily drawn from the foregoing thoughts, the examination of the subject has not been useless: for it is plainly of material consequence to be right in the first principles of a practical question, since real conduct in life and business cannot but be greatly affected by their truth or falsehood. He who thinks eloquence to be the art of deceiving, with Mr. Locke, will, if he be a good man, never study to be eloquent. He who thinks it is speaking ornamentally, will be speaking ornamentally when speaking plainly would be more efficacious. He will, most probably, be lavish of his tropes and figures when these ambitious decorations should be shunned, or employed with the most sparing caution. He who thinks it consists in moving the passions, will often be weeping, unaccompanied by the tears of his audience: and he who thinks it is the art of persuading, will not unfrequently be urgent when he ought to be instructive, or using vehement entreaties instead of powerful proofs. He, and he only, will not be cramped in the exercise of his art by the narrowness of his principles, who *thinks it is the art of speaking and writing in such a manner as is most likely to obtain the end which he proposes to himself in speaking or*

writing. Does he address the multitude? He will aim at being perspicuous, intelligible, and impassioned. Does he speak before men of learning, and such as are eloquent themselves? He will endeavour to be rational and concise. Does he desire to convince? He will reason. Does he wish to give delight? He will be copious, flowing, rich in imagery, and elegant in expression: nothing will be harsh, nothing careless, nothing unpolished or repulsive. Does he mean to agitate or persuade? He will be warm, animated, and glowing. He will arm himself with the thunders and lightnings of eloquence; or will speak in the mildest tone of insinuation, with "'bated breath and whispering humbleness." In short, he will at all times accommodate himself to his situation, and will never be seduced from fidelity to his object.

Yet this is not all his praise, for it is not only on public and solemn occasions that he will find opportunities to use his manifest skill; his eloquence is not only fitted for the bar, the pulpit, or the public assemblies of the state, but for the numberless interesting occurrences of private life; and may even descend to the narration of events, the composition of a letter, or the dexterous management of common conversation. To men who, like myself, have lived in the world, and seen, aye and FELT, real affairs, the utility of such a varied, accommodating, and ready skill, cannot be too obviously apparent. It is thus spoken of by Lord Bacon, and it is set down by him among the desiderata; and with his words I will conclude:—

"Surely it will not be amiss to recommend this whereof we now speak to a new enquiry, to call it by the name, THE WISDOM OF PRIVATE SPEECH; and to refer it to deficients; a thing certainly which the more seriously a man shall think of, the more highly he shall value."

LESSON THE FIRST.

THE NATURE AND PARTS OF RHETORIC.

1. Rhetoric is the art of speaking or writing with persuasion, or that which enables us to apply language or speech to the best advantage, and to attain the object for which it is written or delivered.

2. In composition or discourse we are, according to Cicero, "to consider what is to be said; how and in

what words it is to be said; and, lastly, how it may be ornamented."

3. In every regular discourse will be found an exordium, or introduction; the statement of the subject; the narrative or explanation; the reasoning, or argument; the pathetic part; and the peroration, or conclusion.

4. The object of the *exordium* is to remove the prejudices, and conciliate the good will of the hearers; to awaken their attention, and to render them open to persuasion.

5. In *stating* the subject, clearness and precision should be aimed at; that speaker or writer is best attended to, who briefly and plainly gives the most accurate account of the points in question.

6. The *narrative* of facts should place in the most striking light every circumstance which is to the advantage of the speaker, and soften such as appear to make against him. A perfect narration is one to which nothing can be added, and from which nothing can be taken away without injuring the cause.

7. In the *argumentative* part the speaker should possess logic as a philosopher, and employ it as an orator. He should dispose his arguments in a natural and lucid manner, and express them in such a style and manner as to give them full force.

8. The *pathetic* part must not be continued too long, and should be considered as introductory to the peroration.

9. The *peroration*, or conclusion, must be determined by the nature of the discourse, and the circumstances in which it is delivered: sometimes recourse must be had to a repetition of the argument; sometimes it should assume the tone of pathos; and at others it should rise into dignity and confidence.

10. Besides the parts just mentioned there is frequently room for *digression*, *transition*, and *amplification*.

11. *Digression*, in dry discussions, is useful to relieve

the mind. But it must not be too long, nor introduced too frequently.

12. *Transitions* are forms in speech, used to remind the hearer, in few words, what has already been said, or what is intended to be said.

13. By *amplification* the orator expatiates on a subject in such a manner as to represent it in its full force, to convince the understanding and influence the passions. He ascends from things particular to things general, or descends from things general to things particular; and he amplifies facts from the circumstances of time and place.

QUESTIONS FOR EXAMINATION.

1. What is meant by rhetoric?
2. What is Cicero's rule with regard to composition?
3. What are the parts of a regular discourse?
4. What is the object of the exordium?
5. In what way should the subject be stated, and who will gain the most attention?
6. How should the narration be conducted, and what is esteemed a perfect narration?
7. What is required in the argumentative part?
8. How should the pathetic be managed?
9. Is there any rule for the peroration?
10. Are any other things necessary in a regular discourse?
11. For what is digression useful?
12. What is meant by transitions?
13. What is the object of amplification?

LESSON THE SECOND.

OF WHAT RHETORIC CONSISTS.

1. The ancient rhetoricians distinguished their oratorical compositions into three species; the demonstrative, the deliberative, and the judicial.

2. The *demonstrative* is chiefly conversant in bestowing praise or blame, and comprehends the funeral eulogy so celebrated among the ancients.

3. *Deliberative* eloquence comprehends all matters connected with legislation and government, and can be only cultivated in a free state.

4. *Judicial* eloquence comprehends the whole extent of judicial proceedings, both civil and criminal; that is, the attack and defence of persons and property.

5. In writing, the *style* should possess the following qualities: purity; perspicuity; energy; harmony; dignity; and beauty.

6. *Purity* of style consists in the choice of such words and phraseology as are agreeable to the most general and approved usage of the language in which we write.

7. To attain *perspicuity*, care must be taken to dispose both the words and parts of a sentence in such a manner as best agrees with their mutual connexion and dependence on each other.

8. *Energy*, or vigour of style, depends chiefly on brevity, and a judicious use of tropes and figures.

9. *Harmony* requires sonorousness, uniformity, and variety of cadence; to attain these there must be an intermixture of long and short words, and long and short sentences.

10. *Dignity*, or sublimity, consists chiefly in the selection of the grandest objects, and most striking circumstances, figurative language, brevity, and the use of general terms.

11. *Beauty* of style consists of an union of purity and perspicuity, a moderate use of tropes, and in harmony.

QUESTIONS FOR EXAMINATION.

1. How did the ancients distinguish their compositions?
2. In what is demonstrative eloquence chiefly conversant?
3. What does the deliberative eloquence comprehend?
4. What does judicial eloquence comprehend?
5. What are the properties of a good style?
6. In what does purity of style consist?
7. How is perspicuity attained?
8. On what does energy or vigour of style depend?

9. On what does harmony depend, and how is it attained?
10. In what does dignity or sublimity of style consist?
11. In what does beauty of style consist?

ON STYLE.

Style is the peculiar manner in which a man expresses his conceptions through the medium of language. It differs from mere language or words. Though the words which an author employs be unexceptionable, yet his style may be chargeable with great faults: it may be dry, stiff, feeble, affected. The style of an author is always intimately connected with his manner of thinking; it is a picture of the ideas which arise in his mind, and of the manner in which they do arise. Hence the difficulty of drawing an exact line of separation between the style and the sentiment.

All that can be required of language is to convey our ideas clearly to the minds of others, and at the same time to clothe them in an advantageous dress. The two general heads of perspicuity and ornament therefore comprehend all the qualities of a good style. Perspicuity demands our chief care; for without this quality, the richest ornaments of language only glimmer through the dark; and puzzle instead of pleasing the reader. An author's meaning ought always to be obvious, even to the most careless and inattentive reader; so that it may strike his mind, as the light of the sun strikes our eyes, though they are not directed towards it. We must study not only that every reader may understand us, but that it shall be impossible for him not to understand us. If we are obliged to follow a writer with much care, to pause, and to read over his sentences a second time, in order to comprehend them fully, he will never please us long. Mankind are too indolent to relish so much labour. They may pretend to admire the author's depth after they have discovered his meaning; but they will seldom be inclined to bestow upon his work a second perusal.

LESSON THE THIRD.

OF TROPES.

1. A *trope* differs from a *figure* in this, that the trope refers to a change in the usual meaning of the words; but figures affect the construction of whole sentences.

2. *Tropes* are used to express the various ideas that occur from different associations, and analogies which spring up in the mind on viewing things in different lights.

3. The principal tropes, and those that most frequently occur, are, metaphor; allegory; metonomy; irony; synecdoche; hyperbole; climax; antithesis; prosopopeia; and apostrophe. *Tropes* may be called that sort of language prompted by the imaginations and the passions: and they may be divided into figures of thought and figures of language.

4. A *metaphor* is a comparison, without any words implying comparison. To say a man is "like a lion," is a simile; but to say "he is a lion," is a metaphor; hence Christ is called "a vine," "a door," &c.

5. An *allegory* is a continued chain of metaphors in the same sentence or discourse, when one thing is said, and another meant: thus the Jews are represented in the scriptures under the allegory of a vine, planted, watered, and cultivated by the hand of God, which instead of producing good fruit, brings forth sour grapes:—and the English poet,

> ———————— "Ha! thou hast roused
> The lion in his den, he stalks abroad,
> And the wide forest trembles at his roar.
> I find the danger now,"————

6. A *metonomy* changes the names of things that are naturally, though not essentially, united, as the cause for the effect: thus Mars is put for War; and Bacchus for Wine.

7. *Irony* is a trope in which one thing is said, and the contrary intended: as to say of a notorious rogue, "he is a *very very* honest man." The manner of the speaker gives force to this trope.

8. *Synecdoche* is a trope in which a part is taken for the whole; as "the roof, for the house," "sail, for the ship." We say ten sail of the line, meaning ten ships. Another kind of synecdoche is when "the matter of which the thing is made, is used for the thing itself;" as, "steel for a sword," &c.

9. *Hyperbole* is a trope which exceeds the bounds of strict truth, and represents things as either greater or less than they really are; it is the boldest of all tropes: thus Virgil, speaking of Fame, says,

> "Her head reach'd heav'n, as on earth she stood."

10. *Climax* is when every principal expression in a period adds strength to that preceding it: thus it is said of the joys of heaven, "that eye hath not seen, nor ear heard, neither hath it entered into the heart of man to conceive." We hear of more things than we see, but the imagination can conceive of much more than falls under the cognizance of the senses.

11. *Antithesis* is a contrast drawn between two things, which thereby serves as shades to set off the opposite qualities of each other: a fine instance is given in Cicero's oration against Cataline: "On the one side stands modesty, on the other impudence: on the one side fidelity, on the other deceit: here piety, there sacrilege: here continency, there lust," &c.

12. *Prosopopeia*, or personification, either introduces an absent person as speaking, or one who is dead, as if he were alive and present, or speech is attributed to an inanimate being: thus Anthony vents his passion over the body of his slaughtered friend—

> "O pardon me, thou bleeding piece of earth,
> That I am meek and gentle with these butchers;
> Thou art the ruins of the noblest man
> That ever lived in the tide of times."

13. In an *apostrophe*, the speaker breaks off from the series of his discourse, and addresses himself to some particular person, present or absent, living or dead, or even to inanimate objects: thus Dryden—

> "Farewell! too little and too lately known,
> Whom I began to think and call my own."

QUESTIONS FOR EXAMINATION.

1. In what does a trope differ from a figure?
2. For what are tropes used?
3. Which are the principal tropes?
4. Explain what is meant by metaphor?
5. What is an allegory?

6. What does a metonomy mean?
7. What is meant by irony?
8. Explain the meaning of a synecdoche.
9. What is meant by an hyperbole?
10. What is a climax?
11. Tell me what is meant by an antithesis, and give the example.
12. What is the object of a prosopopeia?
13. In what does an apostrophe consist?

GEOGRAPHY.

UTILITY OF THE STUDY.—OF THE DIVISIONS OF THE SCIENCE, AND THE FIGURE AND MAGNITUDE OF THE EARTH.

"Methinks it would please any man to look upon a geographical map."
Burton's Anatomy of Melancholy.

AMONGST the various branches of science studied in our academies, and places of public education, there are few of greater importance than that of geography, and the use of the globes. The earth is our destined habitation, and the heavenly bodies measure our days and years by their various revolutions. Without some acquaintance with the different tracts of land, the oceans, seas, &c. on the surface of the terrestrial globe, no intercourse could be carried on with the inhabitants of distant regions, and consequently their manners, customs, &c. would be totally unknown to us. The different tracts of land, &c. are described on the surface of a terrestrial globe, but not so minutely as they are on different maps; yet the globe shows the figure of the earth, and the relative situations of the principal places on its surface, more correctly than a map.

Geography is the science that teaches and explains the nature and the properties of the earth, as to its figure, place, magnitude, motions, celestial appearances, &c. with the various lines, real or imaginary, on its surface. The term is derived from two Greek words, which signify the earth, and to describe. It is distinguished from *Cosmography*, as a part

from the whole; this latter considering the whole visible world, both heaven and earth: and, from *Topography*, it is distinguished as the whole from a part. GENERAL or UNIVERSAL GEOGRAPHY, is that which considers the earth in general, without any regard to particular countries; or the affections common to the whole globe, as its figure, magnitude, motion, land, sea, &c. SPECIAL or PARTICULAR GEOGRAPHY, is that which contemplates the constitution of the several particular regions, or countries, their bounds, figure, climate, seasons, weather, inhabitants, arts, customs, language, religion, &c. This science is considered in a still more extensive and comprehensive view by modern mathematicians, who divide it into *Astronomical* and *Physical Geography*. Astronomical Geography comprehends the description of the magnitude and figure of the earth; the measurement of the degree of the meridian in different latitudes, &c. Physical Geography, comprehends the division of the earth, according to the properties of the various substances which compose it, into solid and fluid, air, water, seas, mountains, rivers, &c. &c.

The earth is one of the great bodies which compose the planetary system. It moves round the sun in an orbit nearly circular, and completes its revolution in the course of a year, while at the same time it revolves continually upon its own axis, which is inclined to the plane of its orbit at an angle of 66½ degrees: the time of a revolution being 23 hours and 56 minutes. The revolution of the earth round the sun is called its annual motion, and the rotation it performs on its own axis is called its diurnal motion.

That the earth is nearly of a spherical figure may be proved by many arguments: and since this conclusion has been drawn from phenomena, which were not greatly complicated in their nature, and which were intimately connected with the common affairs of life, it is reasonable to conclude that the attention which was necessary to determine the returns of the proper seasons for performing the labours of husbandry, and for the regulation of civil affairs, would lead men at an early period of society to form pretty just notions of the figure of the earth. When the earth was once known to be spherical, the curiosity of man would naturally lead him to endeavour to measure its dimensions; and we accordingly learn from history, that such attempts were made. But the first accurate measure that was made of the earth, of which we have any certain knowledge, was that executed by M. Picard, in France, towards the end of the last century, and which has been verified se-

veral times since that period. It is not difficult to understand in what way the earth may be measured; the direction of gravity is always perpendicular to the earth's surface; hence it follows that the zenith of any place, or point of the heavens directly over our head, and also the horizon, which is a plane touching the earth's surface at that place, will be continually changing, according as we change our position on the earth's surface. Hence it follows, that as we travel from S. to N., the pole of the heavens, or that point in the heavens in which the earth's axis when produced meets the sphere of the fixed stars, will be more and more elevated above the horizon; the meridian altitude also of the stars in the northern regions of the heavens will appear to increase; while that of the stars in the southern quarter will be diminished. By the elevation or depression of the stars, we shall know the angle formed at the point of concourse of perpendiculars drawn to the earth's surface at each extremity of the terrestrial arc; for this angle is equal to the difference of the meridian altitude of the same star as seen from the extremities of the arc, diminished by the angle which the arc itself subtends as seen from the star; which last angle is altogether insensible. The number of degrees in the arc being found, it is only necessary to determine its length in some known measure, as a fathom, &c.; but as it would be a work of great labour to apply a measure to an arc of great extent, it will be sufficient if its extremities be connected by a series of triangles to those of a base line of 3,000 or 4,000 feet in length; and considering the accuracy with which the angles of these triangles can be observed, the length of the arc may be found with great precision. It was in this way that degrees of the meridian have been repeatedly measured. In France, for example, within these few years, an arc has been measured, extending from Dunkirk to Barcelona; and the degree whose middle is situated in lat. 45°, has by this means been found to be 57,029 toises.*

Although the spherical figure be the most simple, and it is natural for man to suppose objects to be of that form which he most readily conceives, yet the simplicity of nature is not always measured by that of our conceptions. Infinitely varied in her effects, nature is only simple in her causes; and her economy consists in producing a great number of phenomena, often the most complicated, by means of a few general laws. The figure of the earth is the result of those

* The toise is a measure equal to six French feet, and 107 French feet are equal to 114 English.

laws, which, modified by a great variety of circumstances, may cause it to deviate sensibly from a spherical figure: and certain small variations in the length of degrees of the meridian, in France, sufficiently indicated that such a deviation did exist; but the errors, which were unavoidable, in such observations, left this important phenomenon in a state of uncertainty.

The Royal Academy of Sciences in Paris, in which this question had been warmly agitated, concluded with reason, that the difference of magnitude in the degrees of the meridian, if real, would be sensibly perceived by the comparison of degrees measured at the equator and toward the poles. Accordingly, about the year 1735, a company of academicians, composed of the most able mathematicians of France, were sent to the equator, where, having measured a degree of the meridian, they found it to contain 56,753 toises, which was shorter by 274 toises than a degree in lat. 45° N. Other academicians were sent to the north, and having measured a degree of the meridian in Lapland, about the latitude of 66° 20′ they found it to be 57,458 toises, which was greater than the degree at the equator by 685 toises. And by their measurements, the calculations of our own illustrious astronomer, Sir Isaac Newton, were confirmed, and it was completely proved that the earth was not exactly spherical. And in the year 1756, the same Royal Academy of Paris, appointed eight astronomers to measure the length of a degree between Paris and Amiens, and the result was 57,069, for the length of a degree: and other measurements of degrees made since that period, have all tended to shew that the degrees of the meridian gradually increase from the equator to the poles.

Notwithstanding all the admeasurements that have hitherto been made, it has never been demonstrated, in a satisfactory manner, that the earth is strictly a spheriod; indeed, from observations made in different parts of the earth, it appears that its figure is by no means that of a regular spheriod, nor that of any other known mathematical figure, and the only certain conclusion that can be drawn from the works of the several gentlemen employed to measure the earth, is *that the earth is something more flat at the poles than at the equator*. The course of a ship, considering the earth a spheriod, is so near to what it would be on a sphere, that the mariner may safely trust to the rules of globular sailing, even though his course and distance were much more certain than it is possible for them to be. For which and similar reasons, mathematicians content themselves with considering

the earth as a sphere in all practical sciences, and hence the artificial globes are made perfectly spherical, as the best representation of the figure of the earth.

The following table of the dimensions of the earth is given by Dr. Hutton :—

The Diameter	**9,579¾**	**miles**
The Circumference ..	**25,000**	**miles**
A Degree contains ..	**69½**	**English miles**
The Superfices......	**198,944,206**	**square miles**
The Solidity........	**263,930,000,000**	**cubic miles.**

LESSON THE FIRST.

INTRODUCTION AND DEFINITIONS.

1. Geography is a description of the earth as consisting of land and water.

2. The earth is a large globe, nearly 8,000 miles in diameter, continually revolving about the sun, at the distance of ninety-six millions of miles from that body, and turning on its own axis in twenty-four hours.

3. More than two-thirds of the surface of the earth is supposed to be covered with water: the remainder, or land, is said to be occupied by a thousand millions of human beings.

4. The land consists of continents, islands, peninsulas, and isthmuses; and the water of oceans, seas, gulfs, straits, and rivers.

5. The map of the world is divided into two hemispheres. The right, or eastern hemisphere, contains the three continents of Europe, Asia, and Africa, commonly called the Old world, as having been known to the ancients. The left, or western hemisphere, contains the two continents of North and South America, called the New World, having been only discovered by Columbus in the year 1492.

6. An island is a portion of land entirely surrounded by water, as Jamaica, Great Britain, Ireland, &c.

7. A peninsula is a tract of land almost surrounded by water, as the Morea, in Greece. Spain and Por-

tugal, taken together, may be considered as a peninsula, being joined to the continent by the Pyrenean mountains.

8. An isthmus is a neck of land which joins a peninsula to a continent, or two continents together. The tract of land which joins Africa to Asia is the isthmus of Suez; that which unites North and South America is called the isthmus of Panama.

9. There are four oceans; viz. the Pacific, the Atlantic, the Indian, and the Northern Ocean.

10. A sea is a smaller collection of water; as, the Mediterranean, the Baltic, the Black, and White Seas.

11. A gulf, or bay, is an arm of the sea which runs a considerable way into the land; as the Gulf of Mexico and Guinea, and the Bay of Biscay.

12. A strait is a narrow part of the sea, forming a passage from one sea to another; as the Straits of Gibraltar, Magellan, and Dover.

13. A cape or promontory is a point of land jutting out into the sea; as the Cape of Good Hope, and Cape Horn.

QUESTIONS FOR EXAMINATION.

1. What is geography?
2. What is the earth?
3. What proportion of land is there to water on the surface of the earth?
4. Of what parts do the land and water consist?
5. What are the hemispheres?
6. What is an island?
7. What is a peninsula?
8. What is an isthmus?
9. How many oceans are there, and point out by the map how they are situated?
10. What is a sea, and point out those which are mentioned?
11. What is a gulf, and show me those mentioned?
12. What is a strait?
13. What is a cape?

LESSON THE SECOND.

EUROPE.

1. Europe, the smallest of the four divisions of the globe, is bounded on the *east* by the Black Sea and Asia:—on the *north* by the Frozen Ocean:—on the *west* by the Atlantic Ocean:—and on the *south* by the Straits of Gibraltar and the Mediterranean Sea.

2. Europe comprehends Lapland, Norway, Sweden, Denmark, Russia, Prussia, Holland, the German States, Austria, Bohemia, Hungary, Turkey, France, Switzerland, Italy, Spain, Portugal.

3. The principal islands are, Great Britain and Ireland, Iceland, Zealand, Corsica, Sardinia, Sicily, Candia, Ivica, Majorca and Minorca.

4. The three European seas are, the Mediterranean, the Baltic, and the White Seas. That part of the Mediterranean which lies east of Candia is called the Levant.

5. The chief rivers in Europe are the Wolga, the Danube, the Nieper, the Rhine, the Rhone, and the Elbe.* Rivers always rise in the high lands and flow towards the sea.

6. The right bank of a river is that which is on the right hand when sailing *down* the stream; and the left bank on the opposite side.

7. The principal mountains are the Alps, which separate Italy from Germany, Switzerland, and France:—the Pyrenees between France and Spain:—the Dofrafeld Mountains between Norway and Sweden:—and the Carpathian Mountains, which bound Hungary on the north and east.

8. The European capes are North Cape, the Naze, Capes La Hogue, Finisterre, St. Vincent, and Matapan.

QUESTIONS FOR EXAMINATION.

1. How is Europe bounded?
Point out its extent on the map.

2. What countries does Europe comprehend?

Point them out on the map.

3. Which are the principal European islands?

Shew their situation on the map.

4. Which are the European seas?

Shew their position.

5. Which are the chief rivers of Europe, and where do rivers take their rise?

Point out on a map the course of the rivers.

6. Which is the right, and which the left banks of a river?

7. Which are the principal European mountains?

Point out the direction of each range.

8. Shew the European capes, and call them by their names.

LESSON THE THIRD.

NORTHERN EUROPEAN STATES.

1. Lapland, which is covered with immense forests of fir, is divided into Danish, or North Lapland; Swedish, or South Lapland; and Russian, or East Lapland.

2. Lapland is bounded on the north and east by the Northern and White Seas, and on the south and west by Sweden and Norway: its chief towns are Kola and Tornea.

3. Denmark, including Norway, extends from the river Elbe in the south, to the northern extremity of Danish Lapland.

4. Norway is separated from Sweden by the Dofrafeld Mountains: its principal towns are Bergen and Christiana; and near its coast is the famous vortex called the Maelstroom.

5. Denmark is surrounded by the sea, except on the south, where it joins Germany by the province of Holstein.

6. It consists of the peninsula of Jutland, and the islands of Zealand, Funen, &c. in the Baltic Sea. In Zealand is the capital, Copenhagen.

7. Iceland, Greenland, and the Ferroe Islands are subject to Denmark.

8. Sweden is bounded on the north by Lapland, on

the east by Russia, on the west by the Norwegian Mountains, and on the south by the Baltic, the Sound, and the Scaggarac.

9. The chief towns are Stockholm, Upsal, Gottenburg, Carlskroon, and Abo in Finland.

10. Russia, a most extensive empire, is partly in Europe, and partly in Asia; in some parts it is said to be 9,000 miles in length, and nearly three in breadth.

11. Russia is bounded by the Frozen Ocean on the north, by Asiatic Russia on the east, Tartary and Turkey on the south, and by Sweden, Austria, and Prussia on the west.

12. The principal towns are Petersburgh, Moscow, Archangel, Cherson, Astrachan, and Tobolsk.

13. The principal rivers are the Wolga, the Don, the Nieper, and Niester; and the chief lakes are Ladoga and Onega.

14. Prussia is bounded by the Baltic and Russia on the north and east, by Germany on the west, and by Bohemia on the south.

15. The chief towns are Berlin, Koningsberg, Breslaw, Warsaw, and Dantzic; and the principal rivers are the Vistula, the Pregel, and the Memel.

16. It is divided into Royal Prussia, on the west of the Vistula, and Ducal Prussia on the east.

17. Holland is bounded on the north by the German Ocean, on the west by the British Channel, on the east by the German Ocean, and on the south by some of the newly acquired dominions of France.

18. Holland consists of seven provinces, formerly denominated the "United Provinces," viz. Groningen, Griesland, Overyssel, Holland, Utrecht, Guelderland, and Zealand.

19. The chief towns are Amsterdam, Leyden, Rotterdam, Haerlem; and the principal rivers are the Rhine, the Maese, and the Scheldt.

QUESTIONS FOR EXAMINATION.

1. How is Lapland characterized?
2. How is Lapland bounded, and which are its chief towns?

3. What is the extent of Denmark?
4. How is Norway characterized?
5. How is Denmark bounded?
6. Of what does Denmark consist, and where is the capital?
7. What principal islands are subject to Denmark?
8. How is Sweden bounded?
9. Which are the chief towns of Sweden?
Point them out in the map.
10. How is Russia characterized?
11. How is it bounded?
12. What are the principal towns of Russia?
13. Which are the chief rivers?
14. How is Prussia bounded?
15. Which are the chief towns and rivers?
16. How is Prussia divided?
17. How is Holland bounded?
18. Of what does it consist?
19. Which are the chief towns and rivers?

LESSON THE FOURTH.

GERMANY, FRANCE, AND SWITZERLAND.

1. The Austrian dominions are bounded on the west by the German states, on the north by Prussia, on the east by Russia, and on the south by Turkey in Europe, the Gulf of Venice, and Italy.

2. The principal states are Gallicia and Bokovia on the north and east of the Carpathian Mountains: from north-west to south-east are Bohemia, Moravia, Hungary, and Transylvania: and on the south are the Tyrol, Carinthia, Carniola, Croatia, and Sclavonia: Istria is situated on the Gulf of Venice.

3. The chief towns are Vienna, Presburgh, Buda, Cracow, Trieste, and Venice: and the principal river is the Danube, whose length is estimated at 1,300 miles from its rise in Swabia, till it falls into the Euxine, or Black Sea: to this may be added the Morau, the Adige, and the Elbe

4. The principal mountains are the Tyrolese, the Alps, and the Carpathian.

5. The German States are bounded by Denmark and

the Baltic on the north, by Prussia and the Austrian dominions on the east and south, and by France and Holland on the west.

6. Germany is divided into that part which is north of the Mayne, and that which is south of it; both parts are subdived into parts, called circles, and these are again divided into principalities, duchies, electorates, bishopricks, &c.

7. In Germany, north of the Mayne, are the circles of Westphalia, of Upper and Lower Saxony: the duchies of Mecklenburgh, Lunenburg, and Magdeburg: the bishopricks of Osnaburg, Munster, Wurtzburg, &c. &c.

8. In Germany, south of the Mayne, are the circles of Franconia and Swabia: the bishoprick of Mentz, the Palatinate, and Bavaria: the duchy of Wurtemburg: the bishopricks of Spire, Augsburg, &c.

9. The chief towns are Dresden, Hamburgh, Leipsic, Frankfort, Munich, Wurtemburg, Augsburg, and Prague.

10. The principal rivers are the Danube, rising in Swabia; the Rhine, the Mayne, and the Elbe.

11. France, one of the most westerly empires of Europe, is bounded on the north by the British Channel and Holland; by Germany, Switzerland, and part of Italy on the east; on the south by the Mediterranean and Spain; and by the Atlantic on the west.

12. France was formerly divided into provinces; but since the revolution it has been divided into departments.

13. The principal towns are Paris, Lyons, Marseilles, Bourdeaux, Lisle, Valenciennes, Amiens, and Toulouse: the mountains are the Alps, which separate it from Italy; and the Pyrenees, which, till lately, marked the boundaries between France and Spain.

14. The chief rivers are the Rhone, the Garonne, the Loire, the Seine, and the Somme. France is likewise celebrated for its canals, the canal of Languedoc is 180 miles in length.

15. Switzerland, situated among the Alps, is bounded on the north by Germany, on the west by France, and on the south and east by Italy.

16. It is divided into cantons. Its chief towns are Bazil, Berne, Zurich, and Lauzanne.

17. The sources of the Rhine and Rhone, two of the grandest rivers in Europe, are among the mountains of Switzerland. The chief lakes are those of Constance and Geneva.

18. Besides the Alps, which separate Switzerland from Italy, there are the mountains of St. Gothard and Mont Blanc, which are the most lofty of any in Europe.

QUESTIONS FOR EXAMINATION.

1. How are the Austrian dominions bounded?
2. What are the principal Austrian states and kingdoms?
3. Which are the towns and rivers?
4. Which are the mountains?
5. How are the German states bounded?
6. How is Germany divided?
7. What does Germany north of the Mayne chiefly include?
8. Which are the principal circles south of the Mayne?
9. Which are the chief towns?
10. Which are the principal rivers?
11. What are the boundaries of France?
12. How is France divided?
13. Which are the principal towns and mountains?
14. Which are the rivers, and for what else is France celebrated?
15. How is Switzerland bounded?
16. How is it divided, and what are its chief towns?
17. What rivers take their rise in Switzerland; and what are the lakes?
18. Which are the highest mountains in Europe?

LESSON THE FIFTH.

ITALY, TURKEY AND ITS ISLANDS, SPAIN AND PORTUGAL, AND THE UNITED KINGDOM OF GREAT BRITAIN.

1. Italy is bounded by the Adriatic and Mediterranean Seas, and by the Alps, which separate it from France, Switzerland, and Germany.

2. It is divided into the southern part, which comprehends the kingdom of Naples: the central, which

consists of the dominions of the Church, and the kingdom of Etruria; and the northern, which comprehends the kingdom of Italy, including Venice.

3. Rome, Florence, Naples, Milan, are the principal towns; and the Po the chief river. The Tiber has been long celebrated; and so have the lakes Maggiore and Como.

4. Sicily, the largest of the Italian islands, is separated from the south-west of Naples by the Strait of Messina, famous for the Scylla and Charybdis of the ancients. The chief towns of this island are Palermo, Messina, and Syracuse.

5. Sardinia, Corsica, Malta, Candia, and Rhodes, are all considerable islands in the Mediterranean.

6. Turkey in Europe is bounded on the north by the river Niester, and the Austrian dominions; on the east and south by the Black Sea, the sea of Marmora, the Archipelago, and Mediterranean; and on the west by the Gulf of Venice and Dalmatia.

7. It is divided into provinces, of which the northern are Moldavia, Bessarabia, Wallachia, Servia, and Bosnia: those in the middle are Bulgaria, Romania, Macedonia, Albania, and Epirus; and the southern are Thessaly, Achaia, and the Morea, which are called Greece.

8. The chief cities are Constantinople, Adrianople, and Belgrade; and the most celebrated mountains are Pindus and Olympus, which separate Thessaly from Epirus; Parnassus in Livadia; Athos and Hæmus.

9. The islands are numerous, of which Rhodes and Candia, in the Mediterranean, are the chief; besides these there are Zante, Cephalonia, Corfu, and others, west of Turkey, forming a republic of the Seven Islands.

10. Spain, on account of its westerly situation, anciently called Hésperia, is bounded on the north by the Bay of Biscay and the Pyrenean Mountains; on the east by the Mediterranean Sea; on the south by the Straits of Gibraltar; and on the west by Portugal and the Atlantic.

11. Spain is divided into fourteen provinces. Its

chief towns are Madrid, Barcelona, Seville, Corunna, and Cadiz; and the principal rivers are the Ebro, the Tagus, and the Douro.

12. The chief islands near Spain are Majorca, Minorca, and Ivica. Gibraltar stands on a promontory in the south of Spain.

13. Portugal is bounded on the south and east by the Atlantic Ocean.

14. It is divided into provinces, and its chief towns are Lisbon and Oporto. The Azores belong to the Portuguese.

15. The united kingdom of Great Britain and Ireland, consists of England, Wales, Scotland, and Ireland.

16. These islands are situated in the Atlantic ocean; but that part of the ocean south of England is called the Straits of Dover; on the eastern side it is called the German Ocean; and the part between Great Britain and Ireland is called St. George's Channel, or the Irish Sea.

17. England is divided into forty counties; Wales into twelve; and Scotland into thirty-three.

18. Ireland is divided into four large provinces, viz. Ulster to the north, Leinster eastward, Munster southward, and Connaught to the west; and these are subdivided into thirty-two counties.

19. The three capitals are London, Edinburgh, and Dublin. In England the three towns next in importance are Manchester, Liverpool, and Bristol; in Scotland, Glasgow, Perth, and Aberdeen; and in Ireland, Cork, Limerick, and Belfast.

20. The principal rivers in England are the Thames, the Severn, the Humber, the Mersey, the Trent, and the Medway; in Scotland they are the Forth, the Tay, the Dee, and the Don.

21. The islands belonging to Scotland are the Shetland, the Orkney, and the Hebrides or Western Islands; and the most considerable lakes are Loch or lake Tay; Loch Lomond, and Loch Ness.

QUESTIONS FOR EXAMINATION.

1. How is Italy bounded?
2. How is it divided, and of what do the divisions consist?

3. Which are the principal towns and principal rivers?
4. How is Sicily characterized?
5. Which are the considerable islands in the Mediterranean?
6. How is Turkey bounded?
7. How is Turkey divided?
8. Which are the chief cities and mountains?
9. Which are the principal islands?
10. What was Spain formerly called, and how is it bounded?
11. Which are the chief cities?
12. Which are the principal islands, and how is Gibraltar situated?
13. How is Portugal bounded?
14. How is it divided, and what are its chief towns?
15. Of what does the united kingdom of Great Britain and Ireland consist?
16. How is it situated?
17. Into how many counties is the United Kingdom divided?
18. How is Ireland divided?
19. Which are the principal towns?
20. Which are the principal rivers in England and Scotland?
21. Which are the islands and lakes of Scotland?

LESSON THE SIXTH.

ASIA.

1. The extent of Asia from the Hellespont to East Cape is more than 7,000 miles, and its greatest width north and south is about 5,000 miles. Its boundaries are Europe and the Arabian Gulf; the Frozen and Pacific Oceans.

2. Asia comprises, according to Pinkerton, Asiatic Turkey and Russia, the Chinese empire, Japan, the Birman empire, Siam, Hindostan, Persia, Independent Tartary, and Arabia.

3. The Asiatic islands are divided into the Oriental Archipelago; Australasia, or New Holland; and Polynesia, or the small isles in the Pacific Ocean.

4. The oceans and seas adjoining Asia, are the Northern, Indian, and Pacific Oceans: the Black Sea, the Seas of Korea, Tonquin, and Siam; the Bay of

Bengal, the Arabian or Red Sea, the Persian Gulf, the Levant, and the Archipelago.

5. The principal straits in Asia are Bhering's, which separates it from America; the straits of Malacca, Sunda, Java, Sumatra, Ormuz, and Babelmandel, which separates Arabia from Africa.

6. The principal rivers are the Kian Ku; the Koan Ho, the Lena; the Yenisci, and the Ob, the Amur, the Burrampooter, the Ganges, the Euphrates, and the Indus.

7. The mountains, of most consequence, are the Uralian, the Altaian, Swansk, Yablonnoy, the Thamo; those of Thibet, the Taurus; the Gauts of Hindostan; and the Caucasian, which reach from the Black to the Caspian Sea.

8. Asiatic Turkey is bounded on the north by the Black Sea and the Caucasian Mountains; on the east by the Caspian Sea and Persia; and on the south and west by the Red Sea, Arabia, and the Mediterrânean.

9. The chief towns are Aleppo, Damascus, Smyrna, Bassora, and Bagdad. The principal rivers, the Euphrates and Tigris; and the principal mountains, the Taurus, Libanus, and Ararat.

10. Asiatic Russia, or Siberia, is bounded on the north by the Arctic Ocean; on the east by the seas of Kamtshatka and Ochotsk; on the south by the Altain chain of mountains and other lofty ranges; and on the west by European Russia.

11. The chief towns are Astracan, Azof, Tobolsk, Kolywan, Irkutsk.

12. The Chinese empire is of vast extent, and consists of China Proper, the territory of the Monguls, and the region of Thibet.

13. China Proper, is bounded on the east and south by the sea; on the north by the great wall and the Desert of Shamo; and on the west by Thibet. The chief cities are Pekin, Nankin, and Canton.

14. Chinese Tartary, or the territory of the Monguls, is bounded on the east by the sea, on the south by

China Proper and Thibet, on the west by the Cloudy Mountains and Great Bucharia and on the north by Asiatic Russia.

15. Thibet is included between China and Hindostan. The chief town is Lassa.

16. The Japanese Islands have been compared with the united kingdom of Great Britain and Ireland, they form a great insular power near the eastern extremity of Asia, as the British Isles do near the western extremity of Europe.

17. The most considerable of the Japan Islands is Niphon: the chief towns are Jeddo, Miaco, and Nagasaki.

18. The Birman empire is bounded on the north by mountains that separate it from Asia, on the east it borders on Thibet and China, and on the west it is separated by a range of mountains that separate it from the British dominions in Bengal. The chief cities are Ava and Pegu.

19. Hindostan lies to the south of Asia, and extends from Cape Comorin in the south, to the mountains which form the northern boundary of Cashmir. It is bounded by Persia, Thibet, the Birman empire, and the sea. The chief cities are Calcutta, Dacca, Paka, and Benares.

20. Persia has the Caspian Sea and part of Tartary on the north, India on the east, it is bounded by the ocean and Persian Gulf on the south, and Asiatic Turkey on the west. Its chief cities are Ispahan, Shiraz, and Teffliz.

21. Independent Tartary extends east and west from the Caspian Sea to the mountains of Belur, and from the mountains of Gaur in the south to the boundaries of Russia.

22. The divisions of Independent Tartary are, (1.) The Steps, or barren plains in the north. (2.) The kingdom of Kharzan. (3.) Sogd. (4.) Great Bucharia. (5.) The provinces of Balk, Kitan, and Gaur. The chief towns are Samarcand, Bokhara, and Balk.

23. Arabia is bounded by the Red Sea and the Indian Ocean on the west and south, by Persia and the Persian Gulf on the east, and on the north by Asiatic Turkey.

24. It is divided into Stony Arabia, north of the Red Sea, Arabia the Desert on the east, and Arabia the Happy on the south-west. The chief towns are Mecca and Medina.

25. The Eastern Archipelago is divided into the islands of Sunda, Borneo, the Manillas, the Celebesian Isles, and the Spice Islands.

26. Australasia consists of New Holland, New Guinea, New Britain, New Zealand, and Van Diemen's Land.

27. Polynesia includes the Pelew and Ladrone Islands; the Carolines and Sandwich Islands, the Marquesas, Society, Friendly, and Navigator's Islands.

QUESTIONS FOR EXAMINATION.

1. What are the extent and boundaries of Asia?
2. What empires does Asia comprise?
Point them out.
3. How are the Asiatic islands divided?
4. What oceans and seas are adjoining to Asia?
Shew them on the map.
5. Which are the principal straits?
Point them out.
6. Which are the chief rivers?
Trace them out on the map.
7. Which are the principal mountains?
8. How is Asiatic Turkey bounded?
9. Which are the chief towns and mountains?
10. How is Asiatic Russia bounded?
11. Which are the chief towns?
12. Of what does the Chinese empire consist?
13. How is China Proper bounded, and what are the chief cities?
14. How is Chinese Tartary bounded?
15. How is Thibet situated, and what is the chief town?
16. How are the Japanese Islands characterized?
17. Which is the most considerable of the Japan Islands, and what are the chief towns?
18. How is the Birman empire bounded, and what are the chief towns?

19. What are the extent, boundaries, and chief cities of Hindostan?
20. Which are the boundaries and chief cities of Persia?
21. What is the extent of Independent Tartary?
22. How is it divided?
23. What are the boundaries of Arabia?
24. How is Arabia divided?
25. Of what islands do the Eastern Archipelago consist?
26. What does Australasia comprise?
27. What does Polynesia include?

LESSON THE SEVENTH.

AFRICA.

1. Africa, a vast peninsula, in some parts more than 4,000 miles in length, and as many in breadth, lies to the south of Europe, and is separated from Asia by the Red Sea.

2. Africa, according to Pinkerton, is divided into Abyssinia, Egypt, the Mahomedan states in the north-western parts of Africa, the colony of the Cape, and eastern Africa.

3. There are no inland seas, and but one lake of any note, viz., the lake of Maravi; the chief rivers are the Nile, the Niger, and the Senegal.

4. The chief mountains are the Atlas, that reach from Morocco to Egypt; and the Mountains of the Moon, among which the Nile takes its rise.

5. Abyssinia is divided into several provinces, of which the principal are Tigri, Grojam, and Dembea. Gondar is the capital of the empire.

6. Egypt, a kind of valley, through which the Nile flows, is 500 miles in length; and is bounded on the north by the Mediterranean, on the east by the Red Sea and the Isthmus of Suez, on the south by Nubia and Abyssinia, and on the west by Barca.

7. It is divided into Upper, Middle, and Lower. The chief cities are Grand Cairo, Alexandria, Rosetta, and Damietta.

8. Between Egypt and Abyssinia is the ancient Ethiopia, now denominated Nubia, an extensive tract, 600 miles long, and almost as many broad.

9. The greatest part of Nubia is occupied by vast deserts; but Dongola on the north, and Sennaar on the south, are states of some small consequence.

10. The northern Mahomedan states are Tripoli, Tunis, Algiers, and Morocco. Tripoli is Africa Proper, and the Lybia of the ancients: Tunis was formerly the chief seat of Carthaginian power.

11. On the western coast are Sierra Leone; Guinea, divided into the Grain, the Ivory, and the Gold coasts; Benin, Loango, and Congo; Zaara, or the Great Desert, said to be half as large as Europe; and Caffraria, that extends to the Cape of Good Hope.

12. The Cape of Good Hope is the most southerly part of Africa.

13. On the eastern coast of Africa are Natal, Sabia, Sofala, Mocaranga, Mosambico, and Zanguebar, which are succeeded by the desert regions of Ajan and Adel.

14. Madagascar, an island on the east of Africa, is one of the largest islands in the world.

15. On the west is St. Helena, the Cape de Verd and Canary Islands, and Madeira.

QUESTIONS FOR EXAMINATION.

1. How is Africa situated?
2. How is it divided?
3. What is remarkable respecting its waters?
4. Which are the chief mountains?
5. How is Abyssinia divided, and what is the capital?
6. What is the extent, and what are the boundaries of Egypt?
7. How is Egypt divided, and which are its principal cities?
8. How is Nubia situated?
9. With what is Nubia principally occupied?
10. Which are the northern Mahomedan states?
11. What are the principal places on the western coast?
12. How is the Cape of Good Hope situated?
13. What places are in the eastern coast?
14. How is Madagascar situated?
15. What islands are on the west of Africa?

LESSON THE EIGHTH.

AMERICA.

1. America extends from the 72 degree north latitude, to the 54° south latitude, or almost nine thousand miles in length, and in some parts of North America it is more than four thousand miles in breadth.

2. America is divided into North and South, being separated by the Isthmus of Darian and Panama.

3. North America includes the United States, the Spanish and British dominions, besides those parts that are still left to the native tribes.

4. South America, independently of what remains to the native tribes, is divided among the Spanish, Portuguese, French, and Dutch.

5. The inland seas of North America are the Gulfs of Mexico, California, and St. Lawrence, with Hudson's Bay, and Davis's Straits.

6. The lakes, which make one of the grandest features of the world, are Superior, Michigan, Huron, Wennipeg, and the Slave-Lake; and the principal rivers are the Mississippi, the Ohio, and the St. Lawrence.

7. The most celebrated mountains are the Apalachian, passing through the territory of the United States.

8. The United States are divided into the northern, middle, and southern. (1.) The northern include Vermont, New Hampshire, Massachusetts, Connecticut, and Rhode Island.

(2.) The middle consists of New York, New Jersey, Pennsylvania, Delaware, and the territory on the north-west of the Ohio.

(3.) The southern are Maryland, Virginia, Kentucky, North Carolina, Georgia, and the country south of Kentucky.

9. The chief cities are Washington, Philadelphia, New York, Boston, Baltimore, and Charlestown.

10. The Spanish dominions are East and West Florida and the Mexicos. Louisiana formerly made a part of the

Spanish dominions, but was ceded to the United States for a sum of money.

11. The British dominions include Upper and Lower Canada, Nova Scotia, New Brunswick, the Island of Breton, Newfoundland, and the Bermuda, or Summer-Islands.

12. The native tribes possess Greenland, Labrador, and the vast regions about Hudson's Bay, and the country on the western coast.

13. The West Indies, or West Indian-Islands, are situated between North and South America; of these the most important are Cuba and Porto Rico, Spanish; St. Domingo, an independent Black empire; and Jamaica, English.

14. The Bahama Islands are situated north of Cuba and St. Domingo. The Caribbees extend from Tobago in the south, to the Virgin Islands in the north.

15. South America has no inland sea; but the rivers Amazon and those of La Plata and Orinoco are the largest in the world.

16. The mountains are the highest on the globe; the Andes extend four thousand miles, some of which are four miles high, and are perpetually covered with snow.

17. South America comprehends Terra Firma, New Grenada, Guiana, Amazonia, Peru, Brazil, Paraguay, Chili, and Patagonia.

18. Buenos Ayres, Peru, Chili, and New Grenada, belong to Spain; Brazil to the Portuguese; and Guiana partly to the French, and partly to the Dutch; Cayenne consists of a considerable territory on the continent, and of an island of the same name.

19. Amazonia and Patagonia are still possessed by the native tribes, and each is divided into several kingdoms.

20. The islands contiguous to South America are Trinidad, the Falkland Islands, Terra del Fuego, Chiloe, and Juan Fernandez. The Gallipago Islands are near the equator, and the Pearl Islands lie in the Bay of Panama.

QUESTIONS FOR EXAMINATION.

1. Of what extent is America?
2. How is it divided?
3. What does North America include?
4. Among whom is South America divided?
5. Which are the inland seas of North America?
6. Which are the principal lakes and rivers?
7. Which are the most celebrated mountains?
8. How are the United States divided, and what are the northern states?

Which are the middle states?

Which are the southern?

9. Which are the principal cities of the United States?
10. Which are the Spanish dominions?
11. Which are the British dominions?
12. What parts do the native tribes possess?
13. Which are the principal West India Islands, and how are they situated?
14. How are the Bahama and Caribbee Islands situated?
15. Has South America any islands, seas, or rivers?
16. What is said of the mountains of South America?
17. What does South America comprehend?
18. Under whose government are the several parts of South America?
19. By whom are Amazonia and Patagonia possessed?
20. What islands are contiguous to South America?

LESSON THE NINTH.

GENERAL PRINCIPLES.

1. The general curvature of the earth's surface is easily observable in the disappearance of distant objects; for on the sea, when there is no obstruction to the sight, the upper parts of a vessel are first seen, and as the eye is more elevated, each part is sooner observed.

2. The earth is found to be of a globular figure, but not a perfect sphere; the diameter between the poles being about thirty-four miles shorter than the diameter at the equator.

3. The earth is divided into zones and into climates:

there are five zones; two frigid, two temperate, and one torrid zone.

4. The torrid zone is limited by the tropics, which are 23½ degrees on each side of the equator: the frigid zones are within the polar circles, at 23½ degrees from the poles; and the temperate zones are situated between the frigid and torrid zones.

5. The climates are determined by the length of the longest day in different parts of the earth's surface.

6. The natural division of the earth's surface is, as we have seen, into land and water. The lands are more or less elevated above the level of the sea, interspersed with lakes and other collections of water. The Caspian Sea is said to be 300 feet lower than the Ocean.

7. If the surface of the earth were divided into 100 parts, Europe would contain 2, Asia 7, Africa 6, America 6, Australasia 6, and the remaining 73 parts are water.

8. The general inclinations of the continents are discovered by the course of the rivers, of which the principal, and in the order of their magnitude, are the Amazons, the Senegal, and the Nile, the river St. Lawrence, the Mississippi, the Wolga, the Oby, the Amur, the Orinoco, the Ganges, the Euphrates, the Danube, the Don, the Dnieper, and the Dwina.

9. In length the rivers will range differently, viz. (taking the length of the Thames for 1), the Amazons will be 15¼; Kian Ku 15½; the Hoango 13½; the Nile 12½; the Lena 11½; the Amur 11; the Oby 10½; the Jenisei 10; the Ganges, Burrampooter, Ava, and Wolga, each 9½; the Euphrates 8½; the Mississippi 8; Danube 7; Indus 5½; and Rhine 5¼.

10. The level of a continent may be obtained by tracing a line across it in such a direction as to pass no river: this course indicates a tract of country higher than most of the neighbouring parts.

First Exercise.—*With respect to the level of the ancient continent.*—Beginning at Cape Finisterre, we soon arrive at the Pyrenees, keeping to the south of the

Garonne and the Loire. Taking a long turn northwards to avoid the Rhine, we come to Switzerland, and may approach very near the Mediterranean in the state of Genoa, taking care not to cross the branches of the Po. We make a circuit in Switzerland, and pass between the sources of the Danube and of the branches of the Rhine in Swabia. Crossing Franconia, we leave Bohemia to the north, in order to avoid the Elbe; and coming near to the borders of Austria, follow those of Hungary to the north of the Vistula. The Dnieper then obliges us to go northwards through Lithuania, leaving the Don wholly to the right; and the Wolga to pass still farther between Petersburgh and Moscow. We may then proceed eastwards to the boundaries of Asia, and thence northwards to Nova Zembla. Hence we descend to the west of the Oby, and then to the east of the branches of the Wolga, and the other inland rivers flowing into the lake Aral and the Caspian Sea. Here we are situated on the widely extended elevation of India, in the neighbourhood of the sources of the Indus; and lastly, in our way from hence to Kamtschatka, we leave the Jenisci and Lena on the left, and the Ganges, the Kian Ku, the Hoango, and the Amur to the right.

Second Exercise.—*With respect to the direction of the mountains.*—The principal chain first constitutes the Pyrenees, and divides Spain from France, then passes through Vivarais and Auvergne, to join the Alps, and through the South of Germany to Dalmatia, Albania, and Macedonia: it is found again beyond the Euxine, under the names of Taurus, Caucasus, and Imaws, and goes on to Tartary and to Kamtschatka. India is bounded from north to south by the mountains of the Gate, extending from the extremity of Caucasus to Cape Comorin. In Africa Mount Atlas stretches from Fez to Egypt, and the Mountains of the Moon run nearly in the same direction. There is also a considerable elevation between the Nile and the Red Sea.

11. In the New World the neighbourhood of the western coast is in general the most elevated. In North

America, the Blue, or Stony Mountains, are the most considerable; and the mountains of Mexico join the Andes or Cordeliers, which are continued along the whole of the west coast of South America: Chimboracao in Peru is the highest; then Mont Blanc, and the Peak of Teneriffe; the first is four miles high, the second three, and the last two and a quarter.

(The pupil should trace all these in his map.)

QUESTIONS FOR EXAMINATION.

1. How is the curvature of the earth's surface observed?

2. What is the figure of the earth, and what is the difference in the length of the diameter at the equator, and that between the poles?

3. How is the earth divided with regard to zones?

4. How are the zones situated?

5. How are the climates determined?

6. What is the natural division of the earth, and how is the land situated with respect to the sea?

7. How is the surface of the earth divided as to magnitude?

8. How do you trace the general inclination of a continent; and which are the largest rivers, and the order of the magnitude?

9. In what order do rivers range as to their length?

Trace them in the map.

10. How is the level of a continent obtained?

Trace with a pencil the level of the old continent, according to Exercise 1.

Point out the principal chains of mountains according to Exercise 2.

11. Which are the highest mountains?

Point them out.

CHRONOLOGY.

ITS UTILITY.—THE FOUR GRAND EPOCHS IN THE HISTORY OF SCIENCE AND THE PROGRESS OF HUMAN KNOWLEDGE.—THE GENIUS AND PHILOSOPHY OF BACON.

"An Epoch, or Æra, is a certain fixed point of time, made famous by some remarkable event; from whence, as from a root, the ensuing years are numbered, or computed."—*Ferguson's Astronomy.*

Chronology is that science which treats of time, and shews its different measures, or computations, as they have been observed by different nations. By chronology we are enabled truly to date the beginning and end of the reigns of princes, the births and deaths of eminent persons, the revolutions of empires and kingdoms, the progress of civilization, arts and sciences, battles, sieges, or any other remarkable events. Without this useful science, that is to say, without distinguishing the times of events as clearly as the nature of the case will admit, history would be little better than a heap of confusion, destitute of light, order, or beauty. Such are the uses of chronology.

There are at least *four* grand epochs, which are eminently conspicuous in the progress of human knowledge. A description of these will exhibit one of the most important of the applications of which chronology is susceptible; convey a comprehensive idea of historical divisions of time, and gatherings and consolidations of events: and appropriately introduce and illustrate the propositions and rules of the following lessons.—The *first* of these grand epochs, or æras, is the period of unknown antiquity, when the cultivation of knowledge began to be an exclusive occupation, and a separate profession, among those colleges of priests, who, whether established on the banks of the Ganges, the Euphrates, or the Nile, appear to have been the earliest instructors of the human species. These guardians of infant science combined it with religion, and thereby rendered it venerable in the eyes of their untutored contemporaries; but at the same time enslaved it to their own superstition, and for ever stopped its progress at the point where it was bound to opinions held to be sacred and immutable. The useful institution of a distinct body of teachers, thus degenerated into a rigorous exclusion of all other men from learning; and, according to the general sys-

tem of Eastern society, the first division of mental labour was followed by an hereditary monopoly. Impenetrable barriers on every side surrounded knowledge, which hindered it equally from spreading or advancing.

The *second* memorable period, is the emancipation of knowledge in the republic of Greece. It is now vain to inquire by what steps the Egyptian and Phœnician colonists, who carried the arts of civil life to the Pelasgic savages, were gradually led to forsake the peculiar institutions of their forefathers, while they preserved the inventions and manners by which society had been improved. The great revolution, which gave to civilization a freer and more flexible form among the Hellenic nations, is anterior to the dawn of authentic history. At the moment of their first appearance to us, the Eastern monopolies were overthrown; philosophy had thrown off the fetters of superstition; learning was accessible to all men; there was scarcely any separate, still less any hereditary, priesthood; and knowledge occasionally descended to some individuals among that degraded body of slaves, which, by the unhappy constitution of their society, contained the greater part of mankind. Every faculty of human nature was excited to the most intense avidity; and every part of science presented a boundless prospect of improvement. The progress of knowledge, no longer checked, as in Asia, by internal causes, was exposed to danger only from the political causes which affected the quiet and safety of the nations by which it was cultivated, and which finally overthrew the rude governments and feeble independence of these splendid, but turbulent and insecure communities. The structure of their society was not sufficiently strong to afford a lasting protection to the cultivation of knowledge. Greece lost both liberty and independence, as soon as the Macedonians became civilized enough to learn the art of war. The Roman genius did not long survive the downfall of freedom; and universal despotism extinguished national emulation, patriotic feeling, and enterprising ambition, together with talents for literature, skill in arts, and even military spirit, throughout the civilized world. All the objects of generous pursuit which excite the activity of reason and genius, were placed at an immeasurable distance from every Roman provincial. The empire was too vast to be the country of any man; and the province in which each individual was born was too much degraded to be regarded with complacency or pride. Mental refinement, as well as energy, had perished; and nothing but the outward appearance and vulgar enjoy-

ments of civilization were left to be swept away by those illustrious barbarians, who were destined to rekindle the higher principles of human nature.

The *third* period is that known by the name of the middle ages, which comprehends the interval between the fall of ancient civilization and the formation of that system of society which distinguishes Europe in modern times. In the earlier part of this period, the mind seemed once more about to be shackled, and learning was again threatened with oriental bondage. Law and science were the exclusive possession of the priesthood. The whole of the little knowledge then possessed by mankind was not too much for a *single profession*. An infallible church had almost imposed her yoke upon science, and seemed once more upon the point of arresting its progress, by combining the principles of philosophy with the doctrines of her immutable theology. Had not the celibacy of the clergy prevented the sacerdotal office from becoming hereditary, perhaps the Asiatic system might then have been completely re-established. But, on the contrary, as the ecclesiastical profession required labour and study, which the barbarous ignorance of the nobles disdained, the church was the road by which men of the lowest rank rose to the highest station, and thus became one of the most democratical principles of society during the middle ages. A logic, at first allowed only to defend received opinions, at length gave rise to philosophical controversies; which, disguised as they were under a barbarous jargon, contained the seeds of the deepest and boldest speculations concerning the first principles of human knowledge. The revival of the Roman jurisprudence rescued law from absolute dependence on the clergy, and raised up formidable rivals to that body; the cultivation of the vernacular language, and the study of ancient literature, diffused instruction and spirit among the laity; and the mind of man was gradually roused to that revolt against all human authority over reason, which is the grand source of subsequent improvement in science, in art, in government, in morals.

The *fourth* epoch is that of the second emancipation of science, armed with better instruments, supplied with far more abundant materials, and secured from attack or decay by a happier order of society. The reformers, who intended only to arrange the state of theological opinion, restored man to the exercise of free reason. The innumerable inventions and discoveries which began in the middle of the fifteenth century, promoted equally the increase and the diffusion of

knowledge. Civilization became impregnable: the ascendant of civilized nations over the other parts of the human species was no longer capable of being shaken; and, from the beginning of this new career of society, it became impossible to arrest its progress, or permanently to enslave the understanding.

In the general history of the human mind, the Verulamian reformation of philosophy, may doubtless be regarded as a portion of that great revolution by which the fourth epoch is distinguished. But in the history of science it may, with propriety, be separated from the general movement of society, and considered apart as forming a *fifth* epoch in the progress of knowledge.

Columbus, Luther, and Bacon are, perhaps, in modern times, the men of whom it may be said, with the greatest probability, that, if they had not existed, the whole course of human affairs in after ages would have been varied. So much has been said of the genius of Bacon, and of the reformation which he effected in philosophy, that I should prove it to be vain to attempt any additional observation on that subject. But the most important of Bacon's writings has been illustrated by a commentary, small indeed in extent, but, in my opinion, of inestimable value, as it exhibits a perfect model of the method by which the whole of that great work might be adapted to the present state of science. I allude to Mr. Playfair's observations on those parts of the *Novum Organum* which relate to the various sorts of prejudice, and the comparative value of facts in physical enquiry, contained in his admirable discourse on the progress of the physical and mathematical sciences. He thus eloquently describes the mind, and genius, and character of that extraordinary man:— "The power and compass of his (Bacon's) mind, which could form such a plan before hand, and trace not merely the outline, but many of the most minute ramifications, of sciences which did not yet exist, must be an object of admiration to all succeeding ages. He is destined, if indeed any thing in the world be so destined, to remain an *instantia singularis* among men; and, as he has had no rival in the times which are past, so is he likely to have none in the times which are to come. Before any parallel to him can be found, not only must a man of the same talents be produced, but he must be placed in the same circumstances; the memory of his predecessor must be effaced, and the light of science, after being entirely extinguished, must be again beginning to revive. If a second Bacon is ever to arise, he must be ignorant of the

first. The range which Bacon's speculations embraced was altogether immense. He cast a penetrating eye on the whole of science, from its feeblest and most infantine state, to that strength and perfection from which it was then so remote, and which it is perhaps destined to approach to continually, but never to attain. More substitutes might be found for Galileo than for Bacon. More than one could be mentioned, who, in the place of the former, would probably have done what he did; but the history of human knowledge points out nobody of whom it can be said, that, placed in the situation of Bacon, he would have done what Bacon did; no man whose prophetic genius would have enabled him to delineate a system of science which had not yet begun to exist!—who could have derived the knowledge of what *ought to be* from what *was not*, and who could have become so rich in wisdom, though he received from his predecessors no inheritance but their errors." I am inclined, therefore, to agree with D'Alembert, "that when one considers the sound and enlarged views of this great man, the multitude of the objects to which his mind was turned, and the boldness of his style, which unites the most sublime images with the most rigorous precision, one is disposed to regard him as the greatest, the most universal, and the most eloquent of philosophers.

LESSON THE FIRST.

DIVISIONS OF TIME.

1. Chronology is the science which relates to time, and treats of the division of it into certain portions, as days, months, years.

2. The principal divisions of time are those marked out by the revolutions of the heavenly bodies, viz. days, lunar months, and years.

3. A day, in common speech, means that period of time during which the sun remains above the horizon: but in a philosophical sense it denotes the time of a complete revolution of the earth about its axis.

4. The beginning of the day is variously reckoned by different nations: some reckon it from sun-rise, and some from sun-set. In most European nations the day

is computed from midnight, but modern astronomers count the day from noon.

5. By the Jews and Romans the day and night were divided into four watches: the first commenced at six in the morning; the second at nine; the third at twelve; and the fourth at three in the afternoon. The night was divided in a similar manner.

6. The Greeks divided their time into portions of ten days each; the Chinese into those of fifteen days, and the Mexicans into those of thirteen days. But the Jews, Oriental nations, and other civilized people, have made use of weeks of seven days each.

7. In the Old Testament the term week is sometimes applied to a period of seven years, as well as of seven days.

8. The month was at first suggested by the phases of the moon, and hence months were originally lunar.

9. Months are divided into astronomical and civil: astronomical months are measured by the revolutions of the moon, which are either periodical or synodical.

10. The periodical lunar month is computed by the time which elapses between the departure of the moon from any part of her orbit to her return to the same point, which is 27 days, 7 hours, 43 minutes.

11. The synodical month is reckoned from one conjunction of the sun with the moon to another, and its average length is about 29 days, 12 hours, 44 minutes.

12. The civil month is that space of time by means of which the solar year is divided into twelve parts.

13. The solar year is divided into 12 months of 30 and 31 days, excepting February, which contains 28 days, but every fourth year February contains 29 days.

14. The year is measured by the motion of the earth round the sun, and it formerly consisted of 12 lunar months, supposed to contain 30 days each.

15. By Julius Cæsar the year was ordained to consist of 365 days, 6 hours, which is about 11 minutes too long; the true length of the year is 365 days, 5 hours,

48 minutes, 48 seconds: upon this the new style is reckoned.

16. The common year contains, therefore, 365 days, but every fourth year, called leap year, consists of 366 days; to avoid the excess which this would occasion, every hundredth year is common, and contains only 365 days, excepting every four hundredth year, which is to have 366 days.

17. The new style commenced in England in the year 1752, when it it was determined that the year should begin on the 1st day of January, instead of in March, as it had formerly.

Note.—As the form of the year is various among different nations, so is likewise its beginning. The Jews, like other nations of the East, had a civil year, which commenced with the moon in September; and an ecclesiastical year, which began from the new moon in March. The Persians begin their year in the month answering to June. The Chinese and most of the Indian nations begin it with the first moon in March; and the Greeks with the new moon that happens next after the summer solstice.

In England, the civil, or legal, year formerly commenced on the 25th of March, and the historical year on the first day of January. But, since the alteration of the style in 1752, as is above observed, the civil year in this country has likewise begun on the first of January.

At the diet of Ratisbon, in 1700, it was decreed by the body of Protestants of the empire, that eleven days should be retrenched from the old style, in order to accommodate it to the new, and the same regulation has since passed into Sweden, Denmark, and England, where it was established by the 24th Geo. II. c. 23; which enacts, that the supputation, according to which the year of our Lord begins on the 25th day of March, shall not be used from and after the last day of December, 1751; and that from thenceforth the first day of January every year shall be reckoned the first day of the year, and that the natural day next and immediately following the 2nd day of September 1752 shall be called and reckoned the 14th day of September, omitting the eleven intermediate days of the common calendar; and the several natural days succeeding the 14th day, shall be called and reckoned in numerical order. The adoption of the Gregorian computation accordingly took place in 1752, and is now recognized throughout the United Kingdom.

QUESTIONS FOR EXAMINATION.

1. What is chronology?
2. What are the principal divisions of time?
3. What is meant by a day?
4. How is the beginning of the day reckoned?
5. How did the Jews and Romans divide their day and night?
6. How did the Greeks and other nations divide their time?
7. What does a week sometimes mean in the Old Testament?
8. What suggested the periods of months?
9. How are months divided?
10. How is the periodical lunar month computed, and what is its length?
11. How is the synodical month reckoned?
12. What is the civil month?
13. Into how many months is the solar year divided?
14. How is the year measured, and of what did it formerly consist?
15. What was the length of the year as determined by Julius Cæsar, and what is its true length?
16. Explain the length of different years according to the new style.
17. When did the new style commence in England?

LESSON THE SECOND.

CYCLES.

1. The Romans reckoned by *lustra*, periods of five years, so called from a tax required to be paid every fifth year.

2. The Greeks reckoned by *Olympiads*, periods of four years, which derived their names from the public games celebrated every fourth year at Olympia in the Peloponnesus: they are computed from the year 776 before Christ.

3. Cycles are fixed intervals of time composed of the successive revolutions of a certain number of years; there are several cycles in use among chronologists.

4. The lunar cycle is a period of nineteen solar years, at the end of which interval the sun and moon return to very nearly the same part of the heavens.

5. The lunar cycle, on account of its utility in deter-

mining the time of Easter, is called the "Golden Number:" the first year of the Christian æra corresponds with the second of this cycle.

6. The golden number, or year of the lunar cycle, is found by adding 1 to the present year, and dividing by 19, the quotient shows the number of cycles which have revolved since the Christian æra, and the remainder is the golden number for the given year.

Example for the year 1839: to the year I add 1, and divide by 19, $\frac{1840}{19} = 96\frac{16}{19}$. Therefore there have been 96 complete cycles since the birth of Christ, and the golden number for the present year is 16.

7. The solar cycle consists of 28 years, when the sun returns to the sign and degree of the ecliptic which he had occupied at the conclusion of the preceding period, and the days of the week correspond to the same days of the month as at that time.

8. The first year of the Christian æra corresponds to the ninth of the solar cycle: if therefore 9 be added to the present year, and the sum be divided by 28, the quotient denotes the number of the revolutions of the cycle since the ninth year before Christ, and the remainder will be the year of the cycle.

Example for the year 1839, $\frac{1839+9}{28} = \frac{1848}{28} = 66$. Therefore there have been 66 complete solar cycles: and as there is no remainder in this example, the year of the cycle for 1839 is 28.

9. The cycle of Roman indiction consists of 15 years, and the first year of it corresponds to the third year before the Christian æra.

10. To find the year of the Roman indiction, add 3 to the present year, and divide by 15; the quotient gives the number of cycles since the third year before Christ, and the remainder is the year of the cycle.

Example for the year 1839, $\frac{1839+3}{15} = \frac{1842}{15} = 122\frac{12}{15}$. Therefore there have been 122 complete cycles,

and the present year is the twelfth year of the cycle. Had there been no remainder in this and the example No. 6, then the golden number would have been 19: and the Roman indiction 15.

The *dominical*, or Sunday letter in the Almanack, is thus found, the days of the weeks are named A, B, C, D, E, F, G, and A is always put for the first day of the year, B for the second, &c. In the present year, the first day being Tuesday, or A; the sixth, or Sunday will be marked F: of course the dominical letter is F.

QUESTIONS FOR EXAMINATION.

1. How did the Romans reckon?
2. From what period did the Greeks reckon?
3. What are cycles?
4. What is meant by the lunar cycle?
5. By what other name is the lunar cycle called?
6. How is the golden number found?

Give the example.

7. Of what does the solar cycle consist?
8. How does the Christian æra correspond with the solar cycle?

Give the example.

9. Of what does the cycle of the Roman indiction consist?
10. How do you find what year of the Roman indiction answers to any year of the Christian æra?

Give the example.

11. How is the Dominical letter found?

LESSON THE THIRD.

EPOCHS AND ÆRAS.

1. The Julian Period is formed by the combination of the cycles; that is, by multiplying the three numbers into one another: thus $19 \times 28 \times 15 = 7980$, this is the number of years of which the Julian period consists, at the expiration of which, the first years of each of those cycles will come together.

2. The first year of the Christian æra corresponds, or is supposed to correspond, with the 4714th of the Julian period, which is 706 years before the common date assigned to the creation of the world.

3. To find the year of the Julian period corresponding with any given year *before* or *since* the Christian æra. Rule; in the *former* case subtract the year from 4714, and the difference is the answer: in the *latter* case add to the year 4713, and the sum will be the year required.

Example for the present year: 1839 + 4713 = 6552, which is the year of the Julian period.

4. Epochs and æras may be thus explained: an *epoch* is a certain point generally determined by some remarkable event from which time is reckoned, and the years computed from that period are denominated an æra.

Example. The birth of Christ is reckoned an epoch: the years reckoned from that event are called the Christian æra.

5. The most remarkable epoch is that of the creation of the world, which is supposed to have happened 4004 years before Christ. The present year is therefore 4004 + 1839 = 5843rd year from the creation.

6. The universal deluge is another epoch which is computed from the year of the world 1656, or reckoned from the years before Christ, 2348.

7. Two other æras are used in sacred chronology, namely, "The call of Abraham," B. C. 1921, and the departure of the Israelites from Egypt in the year B. C. 1491.

8. Sir Isaac Newton has made use of the Argonautic expedition as an epoch to reckon from, which is supposed to have happened B. C. 1225.

9. The destruction of Troy, B. C. 1183, and the æra of the Olympiads, B. C. 776, are epochs of considerable note in ancient history.

Note.—In order to find the year of the Olympiad, or the year of Rome, in which any event happened, of which we know the date in years before Christ: we have to consider that the first Olympiad took place 776 years before Christ, and that Rome was founded 753 B. C. Hence, we get the following rules. To find the Olympiad: subtract the given year before Christ from 776, divide the remainder by 4, and to the quotient add 1 for the cur-

rent Olympiad, and 1 for the current year of it. The battle of Granicus was fought B. C. 334. Therefore

From	776
Take	334
4)	442
	110 (2
	1 (1
	111 (3

That is, the battle of Granicus, was fought in the third year of the 111th Olympiad.

10. The æra of Nabonassar is another standard to reckon from; this is thus denominated, from Nabonassar, the founder of the Babylonian empire, who began his reign in the year 747 B. C.

11. The æra of the Seleucidæ is reckoned from the establishment of Seleucus, one of Alexander's generals, in the empire of Babylon, 312 years B. C.

12. The Christian æra is dated from the birth of Christ, which is supposed to have happened 4004 years after the creation, and 1839 years before the present period.

13. The Hegira, or Mahometan æra, founded upon the flight of Mahomet from Mecca to Medina, to avoid his enemies, is computed for A. D. 622, of course the the present year 1839 answers to the year 1217 of the Hegira.

QUESTIONS FOR EXAMINATION.

1. How is the Julian period formed?

2. In what way does the Julian period correspond with the Christian æra?

3. What is the rule for finding the year of the Julian period which corresponds with any given year before or since the Christian æra?

4. How are epochs and æras explained?

Give the example.

5. Which is the most remarkable epoch, and what does the present year answer to, reckoning from the creation?

6. From what years is the epoch of the deluge reckoned?
7. What two other æras are noted in sacred history?
8. What æra did Sir Isaac Newton make use of?
9. What other epochs are of considerable note in ancient history?
10. What is meant by the æra of Nabonassar?
11. From what does the æra of the Seleucidæ take its rise?
12. From whence is the Christian æra dated?
13. On what and when was the æra of the Hegira founded?

ARTIFICIAL MEMORY.

ON MEMORY AND MENTAL CULTURE.

"The capacities and powers of the soul plainly indicate her excellency and her value."—*Archbishop Tillotson.*

"Amongst the vast majority of mankind, from the beginning of the world to the present hour, the mental faculties and the higher capabilities of moral and intellectual feeling, have been dormant, and unemployed."—*Quarterly Review, No.* 101.

Memory can restore to its pristine disposition and arrangement all that we have ever felt, all that we have ever thought, and of which no trace remains without us; it can store up unnumbered ideas of the most dissimilar things, without confusion or mixture, for our future use; it can contain within itself the whole circle of arts and sciences, all that ancient and modern history teaches us of remarkable transactions, of the inventions and discoveries of mankind, ever augmenting this enormous stock of knowledge, and at all times delivering to us whatever is best adapted to our present purpose.

Rogers thus beautifully apostrophises this noble faculty:—

"Hail, Memory, hail! in thy exhaustless mine,
From age to age, unnumbered treasures shine!
Thought and her shadowy brood thy call obey,
And place and time are subject to thy sway!
Thy pleasures most we feel when most alone;
The only pleasures we can call our own.
Lighter than air, Hope's summer-visions die,
If but a fleeting cloud obscure the sky;
If but a beam of sober reason play,
Lo! Fancy's fairy frost-work melts away!
But can the wiles of art, the grasp of power,
Snatch the rich relics of a well-spent hour?

These, when the trembling spirit wings her flight,
Pour round her path a stream of living light;
And gild those pure and perfect realms of rest,
Where virtue triumphs, and her sons are blest!"

Pleasures of Memory.

Seneca says of himself, that by the mere effort of his natural memory, he was able to repeat two thousand words upon once hearing them, each in its order; though they had no dependence or connexion upon each other. After which he mentions a friend of his, Portius Latro, who retained in his memory all the declamations he had ever spoken, and never found his memory to fail him, even in a single word. He also mentions Cyneas, ambassador to the Romans from King Pyrrhus, who in one day had so well learned the names of his spectators, that the next day he saluted the whole assembly and all the populace assembled each by his name. Pliny says, that Cyrus knew every soldier in his army by name. Dr. Wallis tells us, that, without the assistance of pen and ink, or any thing equivalent, he was able in the dark, by mere force of memory, to perform arithmetical operations, as multiplication, division, extraction of roots, &c. &c.

How noble are the occupations of the human mind! Of what heights of perfection is it not susceptible! How many great and astonishing things is not man able to execute with it! He thinks and is conscious of it. He forms to himself clear representations of the things that are without him, and can increase the number of these images without end. He compares his ideas with one another, judges of their harmony or their contradiction, and combines them in thousands of various ways. He proceeds from known things to unknown, from the easy to the difficult; adopts principles, draws conclusions, concatenates these conclusions together, and is ever opening new prospects in the unbounded regions of truth that lie before him. Would he dismiss his ideas, they fly from his presence. Are they obscure, he spreads a new light upon them. Are they vanished, he calls them back. With his understanding, man traces his own capacities and powers, and observes the rise, the progress, and the varied combinations of his reflections, his propensities, and inclinations. To cultivate these capacities and powers—these mental faculties—these capabilities of moral and religious feelings—is his first, his most sacred duty.

The acquisition of knowledge is in itself a positive good: the man who has his mind open to the perception of surrounding objects, and is led to inquire into and reflect on

their nature and properties, has much greater capabilities of happiness, has much greater chance of understanding and fulfilling the duties of his station, than if brought up in gross ignorance, without ever having exercised his intellectual powers.'

"There is no situation in life" says an elegant female writer, Mrs. Strutt, in her triumphs of genius and perseverance "so high that must not, after all, owe its highest enjoyments to feelings with which the mind is connected; there is none so low, which may not be cheered and refined from the same source. Independent of all worldly considerations, mental pursuits invariably bestow a rich reward on their votary, in the delight attendant on their cultivation, and the temporary oblivion, at least, of all anxious cares in the abstraction they require."

ARTIFICIAL MEMORY.

1. Artificial Memory is a method of assisting the memory by forming certain words, the letters of which are made to signify the date, æra, &c. to be remembered.

2. The first five vowels *a e i o u* represent, in their natural order, the numbers 1, 2, 3, 4, 5, and from these certain diphthongs are formed; thus, *a* being put for 1, and *u* for 5, *au* will signify 6; *o* standing for 4 and *u* for 5, therefore the diphthong *ou* stands for 9.

3. Certain consonants are used in the same way; thus *b* and *d* being the first two consonants, are put for 1 and 2: *t*, *f*, *s*, and *n*, as initials to the several words, stand for *three*, *four*, *six*, and *nine*.

4. *Five* is represented by *l*; *seven* by *p*; *eight* by *k*,* and also by *ei*, as the two first letters of the word.

5. The *o*, or cipher, is represented by *y* and *z*, as the last vowel and consonant of the alphabet. The *y* is pronounced broad like *w*.

* It is to be observed the *l* stands for 5, because L Roman stands for 50: *p* stands for 7, as the emphatic letter in se*p*tem, seven: *k* stands for eight, as the emphatic letter in the Greek word for eight.

[The following table includes what is necessary to be known previously to the application, and should be committed to memory.]

TABLE.

a	e	i	o	u	au	oi	ei	ou	y
1	2	3	4	5	6	7	8	9	0
b	d	t	f	l	s	p	k	n	z

ILLUSTRATION.—In this table it is seen that *a* and *b* stand for 1 : *o* and *f* for 4 ; *au* and *s* for 6, and so on.

6. Where many ciphers meet together, as 1,000, 1,000,000, &c. then *g* stands for 100, *th* for 1,000, and *m* for million : thus *ag* stands for 100, *ig* for 300, *ath* for 1,000, and *em* for 2,000,000.

7. The learner must next proceed to combine letters to answer to any given figures, or combinations of figures :

Examples.	512 :	891 :	760 :	404
	lad	*koub*	*pauz*	*fyf*

8. The same figures combined will admit of different constructions in the corresponding letters.

Examples.	*nou*	*poil*	*akby*	*othf*
	99 :	775 :	1810 :	4004
	oun	*oipu*	*beiaz*	*fyzo*

[The application of the art will be seen in the following examples, taken chiefly from Grey's "Memoria Technica."]

FIRST EXAMPLE.

General epochas.—Memorial lines

Cr *othf* Dél *etok* Ab *aneb* Ex *áfna* Tém *bybe* Cyr *uts.*
Tróy *abeit* Olym *pois* Rom *put* et Ærnabonás *pop.*
Phíl *ido* Contác *tad* Dioclés *eko* Máhom *audd* Yéz *sid.*

Explanation.

	Bef. Christ.
The CREATION of the World [Cr. *othf*]	. 4004
The universal DELUGE [Dél *etok*] . .	. 2348
The Call of ABRAHAM [Ab *aneb*] . .	. 1921

	Bef. Christ.
Exodus of the Israelites [Ex *áfna*]	1491
The Foundation of Solomon's TEMple [Tém *bybe*]	1012
CYRUS, or the end of the Captivity [Cyr *uts*] .	536
The Destruction of [TROY *abeit*]	1183
The First OLYMpiad [Olym *pois*]	776
The Building of ROME [Rom *put*]	753
ÆRA of NABONASsar [Ærnabonás *pop*] . . .	747
The PHILippic æra, or the Death of Alexander [Phíl *ido*]	324
The Æra of CONTRACts, or of the Seleucidæ, called in the Book of Maccabees the Æra of the Kingdom of the Greeks [Contrác *tad*]	312
	A. D.
The DIOCLESian Æra, or the Æra of Martyrs [Dioclés *eko*]	284
The Æra of the Hegira, or Flight of MAHOMet [Máhom *audd*]	622
The Æra of YEZdegird, or the Persian Æra [Yéz *sid*]	632

SECOND EXAMPLE.

Roman History.—The following lines give the dates when the kings of Rome began to reign; and the number of years which the regal and consular states lasted.

Stat-reg *dol* Consular *oso* Rom *put* et Num *paf*.
Hostil *spy* Anc *sip* Pris *saf* Serv *ups*que Super *lid*.

Explanation.—The regal state under the seven kings lasted 245 years, Stat-reg *dol.*

Consular state, 464 years, Consular *oso.*

		Bef. Christ.
Romulus began to reign . . .	Rom *put* .	753
Numa Pompilius	Num *paf* .	714
Tullus Hostilius	Hostil *spy* .	670
Ancus Martius	Anc *sip* . .	637
Tarquinius Priscus	Pris *saf* . .	614
Servis Tullius	Serv. *ups* .	576
Tarquinius Superbus	Super *lid*	532

THIRD EXAMPLE.

The Twelve Cæsars.

Juli *os* August *el* Tiber *bu* Caligul *ik* Cl *od*
Ner *ul* Galb-Otho *sou* Vit-Vesp *oiz* Tit *pou*
Domit *ka.*

Explanation.

		Bef. Christ.
Julius Cæsar began to reign	Juli *os*	46
Augustus	August *el*	25
		An. Dom.
Tiberius	Tiber *bu*	15
Caligula	Caligul *ik*	38
Claudius	Cl *od*	42
Nero	Ner *ul*	55
Galba } Otho	Galb-Otho *sou*	69
Vitellius } Vespasian	Vit-Vesp *oiz*	70
Titus	Tit *pou*	79
Domitian	Domit *ka*	81

FOURTH EXAMPLE.

The regal table of England since the conquest, and some of the most remarkable princes before it.

Memorial lines.—Casibe *lud* Bóad *aup* Vortig *fos* Heng *ful* et Arth *laf.*
Egbe *kek* Alfré *kpe* Can *bau* Confés *fe* Wil-con *sau.*
Ruf *koi* et Hen *rag.*——
Steph *bil* et Hensée *buf* Ric *bein* J *ann* Heth *dus* et Ed *doid*
Edse *typ* Edter *tes* Rise *tóip* Hefo *toun* Hefi *fád* que.
Hénsi *fed* Edquar *fauz* Esi-*R okt* Hensép *feil* Henok *lyn.*
Edsex *los* Mary *lut* Els *luk* Jam *syd* Caroprim *sel.*
Carsec *sok* Jam *seif* Wil *seik* An *pyb* Gëo *bo*——*doi.*

N. B. After Canute, inclusive, one thousand is to be added to each.

Explanation.

		Bef. Christ.
CASIBELanus chosen commander of the Britons against the invasion of Julius Cæsar [Casibel *ud*]		52
Queen BOADicea, the British heroine, raises an army and kills 7,000 Romans [Boad *aup*]		67
		Aft. Christ.
VORTIGern, who invited the Saxons to the assistance of the Britons against the Scots and Picts [Vortig *fos*]		446
HENGist the Saxon, who erected the kindom of Kent, the first of the Heptarchy [Heng *ful*]		455
King ARTHur, famous for his powerful resistance and victories over the Saxons [Arth *laf*.		514
EGBErt, who reduced the Heptarchy, and was first crowned sole monarch of England [Egbe *kek*]		828
ALFREd, who founded the university of Oxford [Alfré *kpe*]		872
CANute the Dane [Can *bau*]		1016
Edward the CONFESsor [Confés *fe*]		1042
WILliam the CONq. [Wil-con *sau*]	*Oct*. 14.	1066
William RUFus [Ruf *koi*]	*Sept*. 9.	1087
HENry I. [Hen *rag*]	*Aug*. 2.	1100
STEPHen [Steph *bil*]	*Dec*. 2.	1135
HENry the SEcond [Hensée *buf*]	*Oct*. 25.	1154
RIchard I. [Ric *bein*]	*July* 6.	1189
John [J *ann*]	*April* 6.	1199
HEnry the THird [Heth *das*]	*Oct*. 19.	1216
EDward I. [Ed *doid*]	*Nov*. 16.	1272
EDvardus SEcundus [Edse *typ*]	*July* 7.	1307
EDvardus TERtius [Edter *tes*]	*Jan*. 25.	1326
RIchardus SEcundus [Rise *tóip*]	*June* 21.	1377
HEnry the FOurth [Hefo *toun*]	*Sept*. 20.	1399
HEnry the FIfth [Hefi *fád*]	*March* 20.	1412
HENry the SIxth [Hénsi *fed*]	*Aug*. 31.	1422
EDvardus QUARtus [Edquar *fauz*]	*March* 4.	1460
EDward the FIfth } [Edfi-R *okt*]	*April* 9.	1483
Richard III.	*June* 22.	1483

			Aft. Christ.
HENricus SEPtimus [Hensép *feil*]	.	*Aug.* 22.	1485
HENricus octav. [Henoc *lyn*]	. .	*April* 22.	1509
EDvardus SEXtus [Edsex *los*]	. .	*Jan.* 28.	1546
MARY [Mary *lut*]	. . . .	*July* 6.	1553
ELisabeth [Els *luk*]	. . . . . .	*Nov.* 17.	1558
JAMes I. [Jam *syd*]	. . . . . .	*March* 24.	1602
CARolus PRIMUS [Caroprim *sel*]	.	*March* 27.	1625
CARolus SECundus [Carsec *sok*]	. .	*Jan.* 30.	1648
JAMes II. [Jam *seif*]	. . . . . .	*Feb.* 6.	1684
WILliam and Mary [Wil *seik*]	. .	*Feb.* 13.	1688
ANne [An *pyb*]	. . . . . .	*March* 8.	1701
GEOrge I. [Gëo *bo*]	. . . .	*Aug.* 1.	1714
GEOrge II. [Gëo sec *doi*]	. . . .	*June* 11.	1727

FIFTH EXAMPLE.

Chronological miscellanies since the Conquest.

Memorial lines.

God-bul *nou* Chart *eel** Inquis *ded* Tyl *ika* Cade *fly*.
Comp *atze* Gump *atfo* Prin *afon* atque Colum *bont*.
Mar-luth *lap* Prot *alen* Smalcal *loz* Tren-dec *atalfu*.
Mas-par *aloid* Un-p *loin* Sp-in *leik* Powd *syl* Ma-sanel *sop*.
Crom *sli* Jamaic *aull* Crom-mor *suk* capta Gibra *pzo*.

N. B. A thousand is to be added, as above, where it is not expressed.

Explanation.

	Aft. Christ.
Jerusalem regained from the Turks, and GODfrey of BULloigne made king of it [Godbul *nou*]	1099
The INQUISition first erected against the Albigenses [Inquis *ded*]	1222
The Confirmation of Magna CHARTa by King Henry III. [Chart *eel*]	1225
Wat TYLer's rebellion suppressed [Tyl *ika*] .	1381
Jack CADE's rebellion suppressed [Cade *fly*] .	1450
The mariner's COMPass found out [Comp *atze*]	1302
GUNPowder invented in Germany by a monk [Gunp *átfo*]	1344

	Aft. Christ.
The Invention of PRINting [Prin *afon*] . . .	1449
Christopher COLUMbus, a native of Genoa, discovers Cuba and Hispaniola [Colum *bont*]	1493
MARtin LUTHer begins to preach in Germany against Indulgences, and other errors of the Church of Rome [Marluth *lap*] . . .	1517
The name of PROTestants first began on occasion of the protestation the Lutherans made against a decree of the Chamber of Spire against them [Prot *alen*]	1529
The SMALCALdan League, or agreement made between the Protestants of Germany for their mutual defence at Smalcal [Smalcal *loz*]	1540
The Council of TRENt began DEC. 13. [Tren-dec *at-alfu*]	1545
The MASsacre of Protestants at PARis [Maspar *aloid*]	1572
The UNited Provinces, under the protection of William Prince of Orange, throw off the Spanish yoke [Un-p *loin*]	1579
The SPanish INvasion [Sp-in *leik*]	1588
The GunPOWDer treason [Powd *syl*]	1605
The famous rebellion at Naples, on occasion of the grievous excises, headed by MASSANELlo [Massanel *sop*]	1647
Oliver CROMwell usurps the government of England, under the name of Protector [Crom *sli*]	1643
The island JAMAICA in America taken by the English [Jamaic *aull*]	1655
CROMwelli MORS [Crom-mor *suk*]	1658
GIBRAltar taken by the English [Gibra *pzo*] .	1704

Artificial memory may be applied to any circumstance in which the ready recollection of numbers is expedient and useful. As an example: suppose I ride from the City to Fulham by the City-road, Paddington, &c., and wish to remember the check numbers given at the turnpikes without the trouble of tickets. If the

numbers are as follow, then the adjoining words will assist the memory,

OLD STreet turnpike	. .	763	Old St *oisy*
CITY Road	. . . . . .	95	Cit *nu*
BATtle BRidge	. . . . .	540	Bat Br *ufy*
PADdington Road	. . .	889	Pad *kein*
EDGEware Road	. . . .	39	Edge *in*
HYDE Park Corner	. . .	481	Hyde P *oka*
FULham Road	. . . . .	27	Ful *ep*

QUESTIONS FOR EXAMINATION.

1. What is artificial memory?

2. What do the vowels represent, and what numbers are the diphthongs put for, and why?

3. How are the consonants used?

4. Which are the other consonants used?

Why do *l*, *p*, and *k* stand for 5, 7, and 8? See *note*.

5. What do *y* and *z* represent?

Explain the table.

6. What does *g*, *th*, and *m*, stand for?

7. Give some examples of the combinations of figures by letters.

8. Give some instances to shew that the same figures and combinations of figures may be expressed by different letters.

Repeat the lines containing the general epochas.

Repeat the lines containing the regal state of Rome.

Repeat the lines which include the dates when the twelve Cæsars began to reign.

Repeat the lines containing the regal table of England.

Repeat the lines containing the Chronological Miscellanies since the conquest.

MYTHOLOGY.

ON THE IDOLATRY OF MANKIND.

"In deifying the things of nature and parts of the world, they called every thing by the name of God, and God by the name of every thing."—*Dr. Cudworth.*

"They changed the glory of the uncorruptible God into an image made like to corruptible man, and to birds, and to four-footed beasts, and creeping things."—*The Apostle Paul.*

Let us consider the history and extent of idolatry. It is necessary that we should do so, to understand, appreciate, and apply the following lessons. The communications that were repeatedly made to men, concerning the perfections of God, and the way of salvation through the promised Deliverer, must have preserved the human race, during the earlier ages of the world, in the knowledge of the living and true God. Though superstitious practices may have prevailed before the flood, it does not appear that idolatry, strictly speaking, had existence till some centuries after that catastrophe. It is probable that it began in the adoration of the heavenly bodies, the sun, moon, and stars; as we find in the early period in which Job lived, that they were recognised as objects of worship. "If I beheld the sun, when it shined, or the moon walking in brightness; and my heart hath been secretly enticed, or my mouth hath kissed my hand; this also were an iniquity to be punished by the judge, for I should have denied the God that is above.—Job xxxi. 26, 28.

The splendour and usefulness of the sun, and moon, led the Chaldeans and Assyrians, among whom their worship began, to regard them as peculiarly manifesting the divine goodness. It is supposed that a further step, in this species of idolatry, was the adoption of the notion, that the heavenly bodies were either inhabited by superior intelligences, or were themselves living beings, and exerted something like a mediatorial influence with the deity. They were at length fully deified; and those who retained any idea of the supreme God, thought him too far above them to be the object of devotion. This worship of the host of heaven prevailed over a great part of the world, both in ancient and in modern times; and has not been confined to any stage of civilization, or to any rank in society.

Another species of idolatry, and which probably began at an early period, was the worship of deified mortals. It is not unlikely that of these Noah was the first. The traditions respecting a man who, on account of his eminent piety, had been delivered from the deluge, that had swept away the human race, and had been preserved by a miraculous interposition to be the father of mankind, would lead posterity to reverence him, and, as ignorance increased, to adore him. They would soon associate others with him in this honour, who had been the inventors of things useful, and necessary to human life, and who had been benefactors to the nations. Being thus exalted to the rank of gods, they had those attributes ascribed to them, and that religious homage paid to them, which belong only to the true and living God. The Greeks, and Romans, and other pagan nations, raised the chief of their idol deities, to the place of the Supreme Divinity, and represented their Jupiter, to whom the poets ascribed indecent actions, as the father of gods, and king of men, and as exercising universal dominion.

The natural consequence of deifying men, and of regarding one distinguished individual as their chief, to whom they ascribed the titles and attributes of God, was, that their deities were represented as possessed of divine excellences, and of the base passions and vices of mortals. What must have been the state of morals, when among the multitude of the gods there was not one of whom some scandalous thing might not be related, and when even Jupiter, their head, was guilty of actions that ought not to be so much as named?

They advanced however in their idolatrous worship still farther than this. They constituted the images and hieroglyphic symbols of their deities gods. The sun and the host of heaven were not always visible, and as they imagined fire denoted them, they gave to this element, in several eastern nations, divine homage. Many of the lower animals, which were at first, perhaps, used as signs or emblems of the wisdom, power, or goodness of God, became objects of worship. Thus the Egyptians placed the sheep, the goat, the hawk, the crocodile, the cat, and dog, among the number of their god's. The very statues and images which were raised to their deities shared divine honours with them. This was not done among the rude and the savage merely, but by the Athenians and Romans, nor is there a stronger proof necessary of the length to which this species of idolatry was carried at Athens, than the circumstance which is recorded of Scipio the philosopher. He was brought before the tribunal of the Areopagus for saying,

that the statue of Minerva was not a god: and though he endeavoured to defend himself by alleging that it was not a god but a goddess, he was commanded to leave the city. Thus they began to ascribe divine excellencies, and to pay divine honours, not to persons merely, but to things: so that innumerable objects of nature were, on one ground or the other, personified and deified. Nay, so entirely were "their foolish hearts darkened," that they constituted the abstract qualities of things, gods; and in their proneness to polytheism, they extended this honour sometimes to pernicious, as well as to useful, properties and affections. They erected temples, and gave religious homage to the gods of fortitude, health, concord, victory, liberty, and the like. The passions, the diseases, fears and evils, to which mankind are subject, were deified, and had fanes consecrated to their honour. There was scarcely any thing in nature, however monstrous, but some heathen nations worshipped as a god.

Hence the multitude of their gods was endless: gods celestial and terrestrial, who presided over distinct tribes, and cities, and groves, and rivers, and fountains. There they ranked in various orders, but they conceived that to all of them religious worship was due. Even to those of them whom they regarded as evil beings, they gave divine honours. Plutarch, a highly respectable philosopher and historian, mentions certain festivals, and sacrifices, in which some revolting rites were practised, instituted for the pleasing of evil and malignant demons, and averting their wrath. The same fact is attested by Porphyry, who distinguished himself as a bitter enemy of christianity: and the testimony of both affords a comment on the assertion of the Apostle, that "the things which the Gentiles sacrificed, they sacrificed to devils and not to God." The extent of idol worship, and the similarity of the system of idolatry, in all the countries in which it has been practised, are truly amazing.

What is the nature of Idolatry?—I answer thus:—Idolatry consists either in the worship of God through the medium of visible symbols, or in ascribing divine excellence to idols, and giving them religious worship as gods. It has been maintained by some learned men, and especially by Dr. Cudworth, that it was in the former way only that idolatry prevailed over a great part of the heathen world; and that, under the names of heathen deities, the living and true God was worshipped. It is highly probable, if not certain, that idolatry took its rise in this way; but it is very certain also that the worship, which might originally have been intended for the true God, and addressed to him through the idol, was

formerly paid to the idol itself. So much was this the case, that the notion of the true God, as there is the most ample evidence for believing, was almost obliterated, during many ages, in the heathen world. They literally constituted innumerable objects in nature, and the works of their own hands, the gods whom they worshipped. Mankind peopled every region with false deities; among whom they divided the government of the world; some of whom were deemed supreme in their several districts; but all of the same nature and kind. In this way they "changed the truth of God into a lie." The whole system, described and detailed in the following lessons, was a practical falsehood on the being, power, wisdom, and goodness of God. At Athens, and still more at Rome, whose policy it was to give a place to the deities of the nations whom they conquered among those of the empire, you behold a most refined people, paying divine homage to representations of God, the most foolish and false.

The whole system of the Mythology of the heathen, with all the cruel and impure rites of which the worship it involved consisted, was framed so as to strike the senses, and adapted to the human mind in a state of utter darkness and depravity. In their religious festivals, which were celebrated in honour of their gods, their deities were represented as performing the most immoral actions. These actions were ascribed to Jupiter, the chief of their deities, as well as to the inferior gods. The same gods, as St. Austin observes, were laughed at in the theatres, and adored in the temples. Rites the most foolish and immoral were used in their worship, which were prescribed by the laws, established by custom, and countenanced by the magistrates. The offering of human sacrifices, which appears to have been general over the pagan world, was one of these. That it prevailed among the Britons, Germans, and Gauls, we are assured by the testimonies of Cæsar and Tacitus. Among the Romans this inhuman practice prevailed so late as the time of the Emperor Adrian, A. D. 117. Nor can there be given a more revolting proof of its prevalence among this distinguished people, than that when Rome was taken by the Gauls, the most advanced in age and honour gathered themselves together, in the Forum, and after being devoted by the pontiff, consecrated themselves to the infernal gods. In Mexico alone, it has been supposed that not less than twenty thousand human beings were annually sacrificed? In some nations, numerous infants were devoted to destruction, in honour of their god Moloch.

In addition to this most inhuman practice, there were other

cruel rites used in the worship of the gods. The priests of Baal, as we learn from the first book of Kings, ch. xviii. 21—24, "cried aloud, and cut themselves after their manner, with knives, and lancets, till the blood gushed out upon them." At Sparta they whipped boys often till they died on the altar of the goddess Diana. This is not the place to notice the indecent and immoral practices, which were observed over the heathen world, and especially in the civilized nations, in honour of their gods and goddesses. But these practices, together with the gross and general depravity of manners which the system of idol worship produced, furnish an illustration of the Apostle's statement, in the 1st chapter of the Romans, v. 24, "wherefore God also gave them up to uncleanness, through the lusts of their own hearts, to dishonour their own bodies between themselves."

The grossest impurity of manners, the violation of every precept in the decalogue, was sanctioned by custom, if not enjoined by law. Theft was permitted in Egypt and in Sparta. Infants that were weak, or imperfect in form, were exposed and put to death, by the authority of the legislator Lycurgus. Humanity, in the sense that we understand that term, was in a great measure unknown. There was no provision made for the poor, the destitute, and the helpless. Nor is the account which has been transmitted to us, by the page of history, of the sensuality and depravity that pervaded the heathen world, different from that which is recorded by the Apostle Paul in the conclusion of the first chapter of the Epistle to the Romans. "Even as they did not like to retain God in their knowledge, God gave them over to a reprobate mind, to do those things which are not convenient; being filled with all unrighteousness, fornication, wickedness, covetousness, maliciousness; full of envy, murder, debate, deceit, malignity, whisperers, backbiters, haters of God, despiteful, proud boasters, inventors of evil things, disobedient to parents, without understanding, covenant breakers, without natural affections, implacable, unmerciful."—What a picture!

The philosophers and legislators of antiquity, were the supporters and patrons of idolatry.—This I will demonstrate. I know that the contrary is asserted. It is alleged, that they were not idolators themselves, that their doctrines to a considerable extent counteracted the tendency of idolatry, and that the mysteries, which were so generally established, and to which the initiated only were admitted, were expressly designed to preserve the knowledge of the true God. I shall prove that these suppositions are unfounded.

It must be admitted in the outset that they were placed in circumstances in which, whatever might have been their own views of truth and duty, they had it little in their power to influence effectually the notions of the multitude. They wanted the sanction of divine authority to enforce their instructions; they were not the authorized ministers of religion, on whom it devolved to explain the doctrines relating to the gods and to their worship; their opinions, besides, on these matters were so obscure, and so much at variance with each other, that their effect, had they been communicated beyond the walls of the schools, could only be to bewilder, if indeed they had any effect whatever. They therefore despised the people as incapable of understanding their speculations, or of profiting by them. "Philosophy," to use the language of the most eminent of their number, is content with few judges; it designedly shuns the multitude, and is by them suspected and disliked; so that if any man should set himself to vilify all philosophy, he might do it with the approbation and applause of the people." Philosophers, accordingly, so framed the vehicle in which their instructions were conveyed, and in general so wrapped the doctrines of divine things in fables, that they proved of no use in enlightening the people. With the exception of Socrates, who adopted a more familiar strain, their professed aim was, not the religious and moral improvement of mankind, but the exercise and display of their own genius, and the gratification and applause of a few learned men.

Scepticism and Atheism, in Greece and Rome, kept pace with the progress of philosophy, and the world was somewhat advanced before speculative men began to controvert, or deny the existence and agency of God. Aristotle mentions, that all the philosophers before his time asserted, that the world was made by a Supreme Being; and consequently, that they believed in the existence of an intelligent Creator and Governor of all things. Yet, after his time, we know that the most thorough scepticism in regard to this fundamental doctrine of all religion was entertained by men of science and letters. From prudential considerations, they attempted to conceal from the multitude the real nature and tendency of their atheistical speculations and schemes, by pretending a regard for the gods, and for their worship; but the covering was so transparent, that the imposition could not have succeeded, had not the people been immersed in unconceivable ignorance.

When the Romans imported the philosophy of Greece,

they, at the same time, imported the scepticism, and atheism, that attended it. Intent upon conquest and military glory, in the earlier periods of their history, they remained unacquainted with science till near the decline of the consular government. While their greatest men employed their powers, not in speculation, but in studying the arts of war, they probably never questioned the divine origin of their worship, and considered themselves bound to yield a conscientious obedience to the civil and religious institutions of their country. During the first hundred and seventy years of the commonwealth, they strictly observed the law of Numa, which forbade them to make any image, or statue of the divine being, in the form of man or beast, and taught them that it is impious to represent things divine by what is perishable, and that we can have no conception of God, but by the understanding.* But in proportion as they became a literary people, by their intercourse with the Greeks, were their idol deities indefinitely multiplied, and their learned men atheistical in their opinions, and immoral in their practice.

But it will be said, that there were philosophers, both in Greece and Rome, of juster views and a purer character, who entertained the sublimest sentiments, concerning the being, attributes, and providence of God. It can be shewn, however, that they, in place of enlightening and improving the people, gave the sanction of their example and their names in confirmation of the established idolatry; and so mingled truth and error together, as to become the efficient supporters and advocates of idol worship. The most enlightened of them, not excepting even Socrates, spoke of the divinity,—and that to their disciples, when we should expect the greatest accuracy,—in the plural form:—they represented the gods as the creators, preservers, and benefactors of mankind, as seeing and hearing all things, and as being every where present: and thus I think clearly prove, that they understood the divine nature to be peculiar and appropriate, not to one god only, but to many gods, who in common possessed it, and to whom the titles and the character of the Divinity belong.

Their views of the Divinity, besides, were such as could not fail to encourage, if not apparently to justify the people, in giving religious worship to a multitude of gods. Without alluding to all their erroneous opinions on this subject, there was one, which more than any other, seemed to make idolatry a duty, and furnished the most plausible arguments in its favour, namely that the *soul of the world is God*. This

* Plutarch in Numa.

opinion was very general among the heathen philosophers, and was the chief ground of the polytheism of the whole pagan world: concluding, as they did, that because God was all things, and all things God, he ought to be worshipped in all the parts and objects of nature. The Stoics in particular were most strenuous supporters of this tenet, maintaining that the mind which governs the world passeth through every part of it, as the soul doth in us: or, as the poet has expressed it—

> "All are but parts of one stupendous whole,
> Whose body nature is, and God the soul;
> That chang'd through all, and yet in all the same,
> Great in the earth as in the ethereal flame,
> Warms in the sun, refreshes in the breeze,
> Glows in the stars, and blossoms in the trees;
> Lives through all life, extends through all extent,
> Spreads undivided, operates unspent."

In conformity with this doctrine, we find some of the Stoics, after proving the existence and providence of God, from the beauty and order of the works that are made, gravely maintaining that the world is an animal, reasonable, wise, and happy, and therefore is God. I may pause here to remark that I am far from intending to bring against the poet whose lines I have quoted the charge of Spinosism, and Pantheism. I have quoted his lines, because they are susceptible of furnishing an illustration of the doctrine of the ancient Mundi, to those who are acquainted with it. To return, however. On this principal, whatever parts of the universe they chose to deify, were parts of God, and therefore entitled to religious worship. They themselves, also, and their fellow-creatures, were parts of the divinity a notion which tended to produce that pride and self-sufficiency, for which the Stoics were so highly distinguished. On this absurd, but to minds darkened and vain in their imaginations, most plausible ground, did the wisest and the best philosophers of antiquity, advocate the system of polytheism and idol worship; a system which is so totally at variance with what we deem the light of nature which was composed of rites, foolish, indecent and cruel; and which sanctioned the grossest licentiousness and immorality.

The history of the ancient world does not furnish us with a single example of a philosopher who attempted to turn men from the worship of images, statues, and dumb idols, to that of the living and true God. The accusation with which Socrates was charged, and which led to his condemnation and death, was not, that he dissuaded the people from

worshipping the god, appointed by law, but that he himself did not esteem those gods which the city of Athens regarded as such, and that he introduced other new gods. It is mortifying to relate, that this great man, on the day of his death, alluded to a hymn which he had composed in his prison-house to the idol Apollo.

When we remember that the system of idolatry which I have described, was interwoven with the constitution of every government in the world but one, and therefore had the power of the prince, and the magistrate in its support,—that it had the aid and the influence of a priesthood, that was neither unconcerned nor disinterested in its continuance—and that the whole of mankind were its auxiliaries in the feelings of veneration for that supposed sanctity which it awakened, and in the base and potent passions for which it furnished gratification, we may form some feeble conception of the extent of that darkness that covered the earth when our Lord Christ appeared, and of the "gross darkness that covered the people."

LESSON THE FIRST.

ORIGIN AND PROGRESS OF MYTHOLOGY.

CHINESE MYTHOLOGY.

1. Mythology is a word derived from the Greek, signifying any kind of fabulous doctrine; but in a more confined sense it means those fabulous stories concerning the objects of worship, which were invented by men who lived in the early ages of the world.

2. Fable or fiction is a creature of the human imagination, and derives its birth from the love of the marvellous.

Illustration.—The common appearances of nature, which are perpetually occurring, are too obvious, familiar, and uninteresting, either to gratify curiosity or excite admiration; but when by a lively imagination they are new modelled, diversified, and embellished, they generate admiration, and other sensations that interest the mind: of these, legislators and public teachers, in the early ages of society, took a due advantage.

3. The legislator employed fable and fiction as a means of civilizing a rude unpolished world: the philosopher, the theologist, and the poet, made use of the same vehicle to convey their maxims and instructions to the vulgar.

4. Almost every nation has had its peculiar system of mythology; but the Orientalists, who had ever a propensity to personification, have most distinguished themselves in this way.

5. Mythology was first reduced to a system by the pagan priests in Egypt, who were the depositaries of learning as well as of religion, and who monopolized the arts and sciences.

6. Fables and Mythology are the tales of former times; and they cannot prevail to any extent, till the authentic traditions of a people are in a good measure lost, or adulterated by the inventions of men.

7. Hence the Chinese and Egyptians, the two most ancient nations, were altogether unacquainted with fabulous details in the very early periods of their monarchies.

8. By the Chinese mythology, *Fo*, *Fohe*, or *Fohi*, the founder of their empire, was born in a supernatural manner, and was inspired by heaven with knowledge which qualified him to teach all manner of arts and sciences.

9. Of *Confucius*, they say he was not born as other men, and that he was able to speak and reason most profoundly as soon as he was born: a similar fable is given of *Lao-kiun*.

10. The worship of *Fo* was transplanted from India to China, not a century before the Christian æra, by an ambassador who was sent to inquire into the true religion, which an ancient tradition told them, was to come from the West.

11. The god *Fo*, being in high reputation in India, the ambassador collected several images of him, and the canonical books of the Hindoos, and transported them to his own country; he carried likewise with him the

doctrine of the transmigration of souls. Hence sprung the fables of Fo, and all the mythology of China.

QUESTIONS FOR EXAMINATION.

1. What is meant by mythology?

2. From what does fable derive its birth?

How is this illustrated?

3. By whom and for what was fable employed?

4. Who most distinguished themselves in their system of mythology?

5. By whom was mythology first reduced to a system?

6. What is necessary to the prevalence of mythology?

7. What is the inference from this and from fact?

8. What does the Chinese mythology say of their founder Fo, or Fohi?

9. What is said of Confucius and Lao-kiun?

10. From whence and how was the worship of Fo brought to China?

11. In what way were the doctrines and fables of Fo introduced?

LESSON THE SECOND.

HINDOO, PERSIAN, EGYPTIAN, AND PHŒNICIAN MYTHOLOGY.

1. The Hindoo mythology is much connected with the *castes*, into which their nations have been divided from time immemorial: their fables relate to the origin of the universe, to the general deluge, &c.

2. *Fo*, the god to whom the Hindoo mythology is traced, was miraculously born, and at thirty he began to promulgate his doctrines, which extended all over India, and a great part of Asia.

3. His principal doctrine was that of the transmigration of souls, which gave rise to a multitude of idols, in the shape of men, quadrupeds, birds, reptiles, &c.

4. The mythology of the Persians supposes the world to have been repeatedly destroyed and repeopled by creatures of different formation, who were successively annihilated for their disobedience to the Supreme Being.

5. The Persian mythology relates chiefly to the ex-

ploits of Tahmuras, one of their ancient kings, who attacked, vanquished, and carried off the giant or demon that opposed the happiness of his country.

6. The battles, labours, and adventures of Rostan, another Persian chief, are likewise celebrated by the Persian bards, in a similar way to that in which the labours of Hercules have been sung by the poets of Greece and Rome.

7. Persia is said to be the genuine classic ground of Eastern mythology, and the source of chivalry and romance, from which they were propagated to the northern and western parts of Europe.

8. In the Egyptian mythology the revolutions of the heavenly bodies are confounded with the reigns of their most early monarchs.

9. Hence the incredible number of years included in the reigns of their superior gods who filled the Egyptian throne, to whom succeeded twelve demi-gods, who likewise reigned a considerable time.

10. The imaginary exploits and adventures of these gods and demi-gods furnished an inexhaustible fund of mythological romances.

11. The wars, adventures, and exploits of Osiris, Oris, Typhon, and Isis, and the transformation of the gods into divers kinds of animals, are the foundations of Egyptian mythology.

12. Objects animate and inanimate were at first consecrated as the visible objects of the deities, and afterwards they were worshipped as deities. Thus Jupiter Ammon was represented under the figure of a ram; Apis under that of a cow; Osiris of a bull; Pan of a goat; Thoth, or Mercury, of an ibis, &c.

13. Thoth, or Mercury Trismegistus, is thought to have been the inventor of this system: and he is represented as the author of letters, and all the branches of science and philosophy.

14. The Phœnician mythology is built on the details of the fabulous adventures of Uranus, Cronus, Dagon, Thoth, &c. The Phœnicians have also deities answer-

ing to the Pluto, Vulcan, Esculapius, Neptune, Venus, Minerva, and all the Titans of the Greeks.

QUESTIONS FOR EXAMINATION.

1. With what is the Hindoo mythology connected, and to what do their fables relate?
2. What account do they give of *Fo*?
3. What was his principal doctrine?
4. Upon what is the Persian mythology founded?
5. To what does it chiefly relate?
6. To what other hero do the Persian poets refer?
7. How is Persia described with respect to mythology?
8. With what are the reigns of the Egyptian kings confounded?
9. What is the inference drawn from this?
10. How were the exploits of their gods applied?
11. What was the foundation of the Egyptian mythology;
12. By what means did animate and inanimate things become objects of divine worship?
13. Who is the supposed inventor of Egyptian mythology, and what beside is ascribed to him?
14. On what is the Phœnician mythology built?

LESSON THE THIRD.

GRECIAN AND ROMAN MYTHOLOGY.

1. The mythology of Greece is furnished chiefly by the adventures of Jupiter, Juno, Minerva, Neptune, Venus, Mars, Vulcan, and Vesta; Apollo, Diana, Ceres, and Mercury, who represented personages that had been beneficial to their country.

2. The foibles and frailties of deified mortals were transmitted to posterity, and incorporated with the attributes of the deity: hence the mixture of the mighty and mean which chequers the characters of the heroes of the poets of antiquity.

3. Besides the twelve deities already mentioned, and who are called the superior gods, there were the second and third classes of gods, and a multitude of others of inferior dignity.

[*We shall only notice the twelve superior deities.*]

4. Jupiter, the most powerful of the Grecian gods, was son of Saturn and Ops, and having delivered his father from the tyranny of the Titans, became at last master of the empire of the world, which he divided with his brothers; reserving heaven for himself, he gave the sea to Neptune, and the infernal regions to Pluto.

5. Having overcome his enemies he gave himself over to all manner of pleasures, but notwithstanding his licentious conduct, he obtained universal homage and worship.

6. He is represented as sitting on a golden or ivory throne, holding in one hand thunderbolts ready to be hurled, and in the other a sceptre of cypress; these represented his power and its durability: the eagle at his feet with outstretched wings is emblematical of his sovereignty over the heavens.

7. Jupiter was the king and father of gods and men, his power extended over the deities, and every thing and being, except the Fates, were subservient to his will.

8. Juno, the sister and wife of Jupiter, is famous for jealousy, her implacable anger, and her quarrels with her husband: she is represented as seated on a throne, holding in her hand a sceptre, wearing a crown, or having her head encircled with a rainbow: as an attendant, she has her favourite peacock.

9. She presided over empires and riches, and was worshipped with solemnity: she was regarded as the protectress of married women, who invoked her under the name of Juno Lucina. She had three children, viz. Hebe, Mars, and Vulcan. Iris was her chief attendant.

10. Minerva, the goddess of wisdom, is said to have sprung from the head of Jupiter, and was the patron of the arts: she is emblematical of wisdom, prudence, and the other virtues.

11. She is represented as a beautiful woman, armed with a golden helmet and breast-plate: in her right hand is a lance, and in her left is a buckler called the Ægis, on this is embossed the Gorgon Medusa's head, encircled by snakes, instead of hair. The cock and owl are emblems of her valour, and of her propensity to meditation.

12. Neptune was worshipped as the god of the seas: he is represented as standing erect in a chariot, formed of a vast shell drawn by sea-horses; clothed in an azure mantle, and holding in his hand the trident which commanded the waves.

13. He was ruler of the waters, and held dominion over all maritime business: his most remarkable child was Polyphemus, one of the Cyclops, a giant who resided in Sicily, and devoured all those who fell into his hands.

14. Venus, the goddess of love and beauty, is said to have sprung from the froth of the sea, on the surface of which she was wafted along in a shell to the foot of mount Cythera.

15. On the sea she is surrounded by Cupids, Nereids, and Dolphins: but in the heavens her chariot is drawn by doves and swans. Temples have been erected to her everywhere, but Cyprus was her favourite residence.

16. Mars is represented as a furious warrior riding in a chariot drawn by horses, which are driven by a distracted woman. Discord flies before them; clamour, anger, fear, and terror, attend his progress.

17. The dog was consecrated to Mars for his vigilance in the pursuit of his prey; the wolf for his fierceness; the raven, because he delights to feast on the bodies of the slain in battle; and the cock for his watchfulness, by which he prevents surprise.

QUESTIONS FOR EXAMINATION.

1. What chiefly furnishes the mythology of Greece?
2. What is the cause of the mixture of character in the gods of Greece and Rome?
3. Were there any other besides the superior gods?
4. Who was Jupiter, and how did he divide his kingdom?
5. Did he obtain general worship?
6. How is he represented?
7. What character did he sustain?
8. Who was Juno, for what was she famous, and how is she represented?
9. What was her character, and who was her chief attendant?
10. How was Minerva derived, and of what is she emblematical?

11. How is she represented: of what are the cock and owl the emblems?

12. In what character was Neptune worshipped, and how is he represented?

13. What was his character, and who was his most remarkable child?

14. Who was Venus, and from what did she spring?

15. How is she represented, and which was her favourite residence?

16. How is Mars represented?

17. What animals were consecrated to Mars, and why were they devoted to him?

LESSON THE FOURTH.

MYTHOLOGY OF GREECE, ROME, AND THE NORTHERN NATIONS.

1. Vulcan was the god of fire, and the inventor of the art of fabricating arms and utensils from metals. Temples were erected to him at Athens, Rome, Mount Etna, &c.; and at Memphis a most magnificent one was dedicated to this god, before which stood a collossal statue, seventy feet high. He forged the armour of the gods and the thunder of Jupiter.

2. Vulcan is represented seated at his anvil, with his fire and tools about him, holding a thunderbolt with a pair of pincers in his left hand, and in his right a hammer raised in the act to strike; he is supposed to be sooty and black from the nature of his employment. He is the son of Jupiter, the husband of Venus, and the father of Cupid.

3. Vesta was the daughter of Saturn, and the goddess of fire: an altar was raised to her, and certain virgins, called vestal virgins, were employed in maintaining the sacred fire, which burned in honour of the goddess.

4. The temple of Vesta was supposed to contain, besides the sacred fire, the Palladium, or sacred image of Minerva, and the Lares and Penates, or household gods, which Æneas saved from the destruction of Troy

5. Apollo, the son of Jupiter and Latona, presided over the fine arts ; he taught the sciences of divination and of foretelling future events ; and was deeply skilled in the practice of music and medicine.

6. The Apollo Belvidere is the noblest statue in the world : he has a cloak thrown over his shoulders, on his feet are a sort of buskins anciently used in hunting. He holds a bow in his hand. Sometimes he is represented with his harp and crown of laurel.

7. Diana, the sister of Apollo, was goddess of chastity, of the chase, and of the woods. She is adorned as Luna in heaven ; as Diana on earth ; and as Hecate in the infernal regions. She had two temples ; the one at Ephesus, one of the wonders of the world ; the other at Taurica Chersonesus.

8. She is represented under the figure of a tall beautiful virgin, in a hunting dress, a bow in her hand, a quiver of arrows suspended across her shoulders, and her forehead ornamented with a silver crescent.

9. Ceres, the goddess of fruits, is said to have taught the art of tilling the earth, sowing corn, and making bread. She is represented as a majestic woman, with poppies and ears of wheat in her left hand, and a lighted torch in her right.

10. Mercury, the messenger of the gods, was the inventor of letters, the reformer of language; on account of his attention to eloquence he was denominated Hermes.

11. He is represented as a young man of a cheerful countenance, with wings fixed to his cap and sandals, and in his hand the caduceus, a wand, round which were entwined serpents.

12. The mythology of the northern nations has no affinity with that of the Greeks, but is much like that of the Persians. Odin or Woden was the supreme divinity of those people ; his exploits and adventures furnish the great part of their mythological creed. That hero is supposed to have emigrated from the east ; he is represented as the god of battles, and as killing thou-

sands at a blow. His palace is called Valhalla; it is situated in a city where the souls of the heroes who had bravely fallen in battle, enjoy supreme felicity. They spend the day in mimic hunting matches, or imaginary combats; and at night they assemble in the palace of Valhalla, where they feast on the most delicious viands, dressed and served by virgins, adorned with celestial charms, and flushed with the bloom of everlasting youth. They solace themselves with drinking mead, the nectar of the country, out of the skulls of enemies whom they had killed in battle.

QUESTIONS FOR EXAMINATION.

1. Who was Vulcan, where were his temples, and what was his business?
2. How is he represented?
3. Who was Vesta, and what was the business of the Vestal virgins?
4. What did the temple of Vesta contain?
5. Who was Apollo, and what did he teach?
6. How is the Apollo Belvidere represented?
7. Who was Diana: under what names was she adored, and where were the temples dedicated to her?
8. How is Diana represented?
9. Who is Ceres, what did she teach, and how is she represented?
10. Who is Mercury, of what was he the inventor, and why was he denominated Hermes?
11. How is he represented?
12. Give some account of the mythology of the northern nations.

HISTORY.

OBSERVATIONS UPON ITS NATURE, GENIUS, OBJECTS, POWERS, AND EFFECTS.

"When a statesman traces, for the instruction of posterity, the living images of the men and manners of his time; the passions by which he has himself been agitated, and the revolutions in which his own life and fortune were involved; the picture will doubtless retain a strong impression of the mind and character, and the opinions of its author. But there will always be a wide interval between the bias of sincere conviction, and the dishonesty of intentional misrepresentation."

LORD GRENVILLE,—*his preface to the earl of Chatham's Letters to his nephew, Lord Camelford.*

IT did not escape the sagacity of Tacitus, that the decline of history under the imperial government was, in part, caused by the exclusion of the people from public affairs. In popular states, even where the historian himself has no direct experience of public business, he at least breathes an atmosphere full of political traditions and debates. He lives with those who think and speak more of them than of most other subjects. He cannot be an utter stranger to the spirit of civil prudence. Under absolute monarchies, on the other hand, the few who know the causes of events, are either afraid to write, or see no importance in any thing but the intrigues by which they obtain and preserve power; and the task of writing history is necessarily abandoned, either to mere compilers, or to sophists or rhetors, who, of all men, are the most destitute of insight into character, and of judgment in civil affairs.

The genius of history is nourished by the study of original narrators, and by critical examination of the minute circumstances of facts. Ingenious speculation and ostentatious ornament, are miserable substitutes for these historical virtues; and their place is still worse supplied by the vivacity or pleasantry which, where it is most successful, will most completely extinguish that serious and deep interest in the affairs of men which the historian aims to inspire. An historian is not a jester or a satirist. It is not his business to sneer or laugh at men, or to lower human nature. It is by maintaining the dignity of man, and the importance of his pursuits, that history creates a fellow-feeling with his passions, and a delight in contemplating his character and actions.

"My work," says M. de Sismondi, in the introduction to his History of France, "was begun and completed from the originals, according to the advice which I formerly received from the great historian, John de Muller. I studied history in the contemporary writers: I endeavoured to represent it in the light in which it appeared to them; and it is only after having exhausted these original authorities, and formed an unprejudiced opinion from them, that I had recourse to subsequent writers. Then only I often learned the existence of historical controversies, of which I had not before suspected the possibility. I have lost something by this process; but the contrary method would, I think, have been more injurious. History, thus contemplated at its source, appears to me so new, so different from what I supposed it to be, that I seem to myself to have gained more by guarding against the prejudices of compilers, than I can have lost by renouncing the aid of their information."

Though this language may seem to indicate too rigorous an exclusion of modern aid, there is nothing more certain than that the history of remote ages can never be composed as it should be, unless it be chiefly drawn from original writers. The importance of this practice to truth is obvious: yet no man without experience can know the full extent of the danger of trusting even to the best compilers. In long works oversights are inevitable; and, in the course of time, small inaccuracies are, by the negligence of successive compilers, magnified into considerable, and sometimes essential errors. Whoever traces a remarkable story through a long series of historians, will often be astonished at the utter dissimilarity of the last, to the first edition, though in each intermediate stage the additions or alterations may be almost imperceptible. There are few countries in which the truth of history has suffered more than in England, from the indolence with which almost every one of our modern historians has taken the basis of his narrative from his predecessor. A better spirit has, however, in some modern works been displayed; and, when government have done their duty, by making public the ample materials under their controul, we may hope to see our ancient history illustrated from authentic sources.

But it is not to accuracy only, that the consultation of original authorities is essential. The delight with which we peruse the history of ages long passed, depends chiefly on its lively and picturesque representation of men, manners, and events. But these are only to be found in the dramatic nar-

rative of the eye-witnesses, or the contemporary who had always seen the manners which he paints, and had generally felt some degree of the passions which actuated his heroes. The spirit of the original narratives evaporates when they are poured from compilation to compilation. If a modern historian can recover this charm, it is only when he either borrows directly from the first sources, or when frequent and familiar contemplation of them has kindled his imagination, and enabled him to *antiquate* his feelings, so as to become for a moment the contemporary of those ages of which he is the historian. Nothing, therefore, is more true, however paradoxical it may seem, than that the means of amusement, and what is more, of interest, are to be found by a modern writer of adequate talents, chiefly in those researches into antiquity, and that diligent study of ancient writers, which appear so tedious to indolent readers, and may be represented in so ludicrous a light by men of wit. The narrative of ancient events, by a mere modern thinker, must always be uninteresting, because he can never paint, or even conceive, the feelings from which these events arose.

It is on the sympathy which history excites, that its moral effect depends. The moral improvement to be derived from all narrative, whether it be historical, or what is called fictitious, is in proportion to the degree in which it exercises, and thereby strengthens, the social feelings and moral principles of the reader. In both cases it excites emotions similar to those inspired by the men and actions which surround us in the world. Our habits of moral feeling are formed by life; and they are strengthened by the pictures of life. In the perusal of history or fiction, as in actual experience, we become better by learning to sympathize with misfortune, and to feel indignation against baseness. The narrative of events which have occurred, or which may probably occur, is thus one of the most important parts of the moral education of mankind. It is not, however, by the common-place and trivial moralities which may be inferred from, or illustrated by every narrative, that the historian contributes to the morality of his readers. These general conclusions are already known to every child; and nothing has less effect on the character or feelings than the repetition of such paltry adages. He can improve his readers only by interesting them; and he can interest them only by that animated representation of men and actions which inspires feelings almost as strong as those which are excited by present realities. Delight and improvement must, therefore, be produced by the very same

means; and if the history of former ages be delightful only when it has the picturesque particularity of original writers, it must depend also in part, on the study of the same writers for the attainment of its highest purposes.

Nor are these the only circumstances in which history, when rendered picturesque and characteristic by its adherence to contemporary documents, is superior to those narratives in which modern speculation predominates. It is not only more accurate, more interesting, and more moral, but it also affords more instruction to the politician, and better materials for the philosopher. As long as the events preserve the colour of the age in which they passed, the statesman is in no danger of being so misled by history as to consider the precedents of a remote antiquity as fit to be slavishly adopted in a totally dissimilar condition of society. The speculations of a modern compiler discolour, and disfigure, and disguise the facts of ancient history. They are seen through a different medium; and being combined with modern passions and prejudices, are, indeed, no longer the same facts. From such materials the philosopher can form no true judgment of the spirit and character of former times. No inferences from them can afford a solid foundation for a theory of the nature and progress of society.

To illustrate these general remarks, I will subjoin a specimen of the difference between an ancient narration, and a modern abridgment. In speaking of the administration of Charles Martel, the Abbé Velly, in his History of France, has the following passage.—

"France owes to the victory of Poictiers, the preservation, or at least the free exercise, of the Christian religion. Without the intrepid arm of the prince, who crushed the Saracens, she might have been compelled, perhaps, to embrace Mahometanism; yet the clergy laboured to blacken his memory. We read in a synodal letter ascribed to Hincmar, that the body of Charles was carried away to hell; and that on opening his grave, nothing was found but a frightful dragon, and a pestilential smell. This ridiculous story is founded on a revelation of St. Eucherius of Orleans, though that prelate died before Charles Martel. It is obvious that it is a fable invented to intimidate those princes who might be tempted to lay their hands on the property of the church."

Velly, Hist. of France, p. 183.

Let us now see the ancient narrative, as it is in my opinion judiciously copied literally by M. de Sismondi. A hundred and

twenty years after the death of Charles Martel, the clergy of France, assembled at Kiersi in a national council, condemned his memory in the following letter to Louis the Germanic.

"It is because prince Charles, father of king Pepin, was the first of the kings and princes of the Franks, to divide and separate the property of the church, that, for that cause alone, he is damned eternally. We know in fact, that St. Eucherius, bishop of Orleans, whose body rests in the convent of St. Frudon, being in prayer, was carried into the world of spirits; and that among the things which he saw, and which the Lord showed him, he recognized Charles exposed to torments in the lowest depths of hell. The angel who conducted him being interrogated on this subject, answered, that in the judgment to come, the soul and body of him who takes away the goods of the church, shall be exposed even before the end of the world, to eternal torments, by sentence of the saints, who are to judge with the Lord. The sacrilegious plunderer shall be laden with the penalties, not only of his own sins, but of the sins of those who had bestowed their property, for the love of God, on holy places, on the lamps of divine worship, on alms to the servants of Christ, and for the redemption of their own souls. St. Eucherius, when he came to himself, called St. Boniface and Fulrad, abbot of the convent of St. Dennis, and first chaplain of king Pepin, to whom he related these things. He recommended that they should go to the sepulchre of Charles; and that if they did not find his body there, it would be a proof of the truth of the vision. Boniface and Fulrad accordingly went to the convent, where the body of Charles had been interred; and, having opened his tomb, a dragon instantly sprang out of it, and it was blackened in the inside, as if he had been burnt. We ourselves have seen men who lived till our times, and who were present at these occurrences, and they attested the things which they saw and heard. These things coming to the knowledge of Pepin, he caused a synod to be assembled at Leptines, at which St. Boniface, together with George, a legate of the apostolic see, presided. We have the acts of this synod, which attempted to restore all the ecclesiastical property which had been taken; but as Pepin could not restore them all, on account of his war with Gaifer, prince of Aquitan, he at least mortgaged them to bishops, directing that they should pay tithes, and that each household pay twelve pennies to the church, till the whole could be restored."

How faint is the modern abridgment; and in what lively colours does the original letter display the sordid rapacity, the rancorous malice, the impudent imposture, the gross ignorance, of a whole national church, and the wretched state of nations and sovereigns, who could be duped by such clumsy falsehoods!

I cannot forbear from copying a singular, powerful, and impressive passage from Hobbes's remarkable preface to his translation of Thucydides. It is as follows: "The principal and proper work of history being to instruct and enable men by the knowledge of actions past, to bear themselves prudently in the present, and providently towards the future, there is not extant any other (merely human) that doth more fully and naturally perform it, than this of my author. It is true, that there may be many excellent and profitable histories written since; and in some of them, there is inserted very wise discourses, both of manners and policy: but being discourses inserted, and not of the contexture of the narration, they, indeed, commend the knowledge of the writer, but not the history itself; the nature whereof is merely narrative. In others, there be subtile conjectures at the secret aims, and inward cogitations of such as fall under their pen; which is also none of the least virtues in a history, where the conjecture is thoroughly grounded, not forced to serve the purpose of the writer in adorning his style, or manifesting his subtlety in conjecturing. But these conjectures cannot often be certain, unless withal so evident, that the narration itself may be sufficient to suggest the same also to the reader. But THUCYDIDES is one, who though he never digress to read a lecture, moral or political, upon his own text, nor enter into men's hearts, farther than the actions themselves evidently guide him, is yet accounted the most politic historiographer that ever writ. The reason whereof I take to be this: that he filleth his narrations with that choice of matter, and ordereth them with that judgment, and with such perspicuity and efficacy expresseth himself, that as Plutarch saith, he maketh his *auditor a spectator*. For he setteth his reader in the assemblies of the people, and in the senates, at their debating; in the streets at their seditions; and in the field at their battles! So that look how much a man of understanding might have added to his experience if he then lived a beholder of their proceedings, and familiar with the men and business of the time: so much *almost* may he profit now, by attentive reading of the same here written. He may from the narrations draw out lessons to himself, and

of himself be able to trace the drifts and counsels of the actors to their seat."

The truth it will be said is here somewhat exaggerated. It would require infinite dexterity, as well as a continual sacrifice of vanity, to write in this manner; but, nevertheless, so far as it is attainable, how instructive and how delightful!

Even HUME, who tells his story so well, is often ostentatious of his opinions, and becomes, like Gibbon, rather a philosophical commentator, than a skilful historian. So does a greater writer still, Burke, both in his 'Account of the European Settlements,' and in his masterly 'Fragments of English History,' which I trust every one of *my* readers will read: but he never is deficient in vivacity and variety. One source of both those excellencies may be found in the judicious practice of borrowing freely from the original writers, and from the documents of the times, altering the expression only by discarding obscure, uncouth, and redundant words.

How striking is this short passage, in a speech of Edward the Fourth, to his parliament! "The injuries that I have received are known every where, and the eyes of the world are fixed upon me to see with what contenance I suffer." If actual events could be often related in this way, there would be more BOOKS in circulating libraries than novels and romances.

The lively and graphic style is plainly the best, though now and then the historian's criticism is wanted to support a startling fact, or to explain a confused transaction. Thus the learned Rudbeck in his "Atlantica," ascribing an ancient temple in Sweden, to one of Noah's sons, warily adds, "'twas probably the youngest."

I cannot help adding, that if the student will read with a pencil in his hand, more than one celebrated historian, he will be surprised to find himself making so many grave observations, worthy of the cautious Swede!

There is one grand incident in our own annals, presenting the means of producing a work at least as interesting and instructive, as any public story ancient or modern. I mean the establishment of American Independence. Do I say too much in speaking of this, as the principal event of all civil history?

I will appeal to the student; I will ask him only to think of the magnitude and the nature of the question at issue; of its consequence as an example; of the successful termination of the struggle; of the elevated and accomplished actors, both in the United States and in England. The battle was

as much fought at home as abroad; and some of the combatants were the King, Lord Chatham, Lord North, Mr. Burke, Mr. Fox, General Washington, Dr. Franklin, and Mr. Jefferson. I will ask him to think too of the manifestoes, the proclamations, the declaration of Independence; and, "last not least," of the speeches, which furnish abler and more authentic examples of eloquence, than are found in Thucydides, Livy, or Tacitus. These dramatic documents have always been the allowed and admired ornaments of history.

One surprising instance, equally honourable to the speaker and to the assembly that bore it, shall conclude this paper; it is the famous exclamation of Lord Chatham, "My Lords! I rejoice that America has resisted." Let the student remember that this man had been minister, and meant to be minister again!

I hope these random thoughts will not perplex, but incite the student to the exercise of critical acumen and philosophic reflection.

LESSON THE FIRST.

1. History is a connected recital of past or present events: and it is the office of history to trace the progress of man from the savage state, and through the several degrees of civilization, to the nearest approach to perfection of which social institutions are capable.

2. The uses of history are these: it serves to amuse the imagination and interest the passions:—it improves the understanding; and it tends to strengthen the sentiments of virtue.

3. Oral tradition was, in early times, the only vehicle of historical knowledge: hence to secure the remembrance of important facts, as compacts, treaties, &c. they were recited in the assemblies of the people.

4. Another method of transmitting the knowledge of important events was by historical poems. Hence the office of bards, whose whole employment was to compose and repeat those poems.

5. The next method of preserving traditions was by visible monuments, as pillars, edifices, &c. erected upon

occasion of any remarkable event: of this nature was the heap of stones raised by Jacob and Laban, as a memorial of their mutual reconciliation.

6. Coins, medals, and inscriptions, may be regarded as portable historical monuments. In after times the archives and laws of states perpetuated information in a more certain and extended form.

7. A general and accurate knowledge of geography and chronology is necessary in the study of history.

ILLUSTRATION.—A knowledge of the situation and relative magnitude of the several countries of the earth assists and affords clear and distinct ideas of events; and a general comprehension of the current of time enables a person distinctly to trace their dependence on each other.

8. A good historian should have a general acquaintance with the sciences, and with the principles which actuate human nature, as it will enable him to judge of the possibility and probability of certain facts, and be a guide in estimating the consistency of human characters, and of what is, or is not, within the powers of human nature.

ILLUSTRATION.—Philosophical knowledge, in general, will be found of the most extensive use to all persons who would examine with accuracy the achievements of ancient nations in peace or war, or would impartially weigh the account of any thing in which the powers of nature are employed.

9. Useful aids in the study of history are well drawn compendiums, such as that of Holberg, translated and improved by Sharpe; chronological tables, such are Blair's; and historical charts, as that by Priestley; these shew in a single view the reference and connexion which the history of one country has with others.

10. History, with regard to the *nature of its subjects*, may be divided into general and particular; and, with respect to *time*, into ancient and modern.

11. General history relates to nations and to every thing of a public nature connected with them: the sub-

ject of particular history refers to individual countries or particular periods.

12. Ancient history commences with the creation of the world, as given by Moses, and extends to the reign of Charlemagne, A. D. 800. Modern history is dated from that period, and extends to our own times.

13. General history is divided into *civil* and *ecclesiastical:* the first contains the history of mankind in their various relations to one another: the second considers them as acting, or pretending to act, in obedience to what they believe to be the will of God.

QUESTIONS FOR EXAMINATION.

1. What is history and its office?
2. What are the uses of history?
3. What was the first vehicle of historical knowledge?
4. What was the second method of transmitting historical facts?
5. Mention another method.
6. What are called portable historical monuments?
7. What is necessary in the study of history?
Give the illustration.
8. With what should an historian be acquainted?
Give the illustration.
9. What are reckoned useful aids in the study of history?
10. How is history divided?
11. To what does general and particular history relate?
12. When does ancient and modern history commence?
13. How is general history divided, and what do the parts contain?

LESSON THE SECOND.

1. History resolves itself into certain periods, at each of which a great revolution took place, either with regard to the whole world, or a very considerable part of it.

2. The *first* general period refers to transactions from the creation of the world to the flood, which are recorded in the first six chapters of the Bible.

3. In that period men were not in a savage state: they had made some progress in the mechanic arts;

had invented music, and found out the method of working metals.

4. They lived in one large community without any divisions into different nations, which at length proceeded from the confusion of languages.

5. The *second* period of history commences at the deluge, about 1656 years after the creation, and it extends to the beginning of profane history.

6. It includes the attempt at building the tower of Babel; the history of Noah's sons; the foundation of the kingdoms of Babylonia and Assyria; the migration and history of the Israelities; the history of the Greeks, and their expedition against Troy; the founding of Carthage and Rome.

7. The *third* period begins with the 28th Olympiad, about the year B. C. 668; and it includes the destruction of the kingdom of Assyria by the Medes and Babylonians, and the overthrow of the kingdom of Judea by Nebuchadnezzar, king of Babylon.

8. The *fourth* period of history extends only to the conquest of Babylon by Cyrus, a period of thirty-one years, which event took place in the year B. C. 538.

9. During the *fifth* period, the Jews, under Cyrus, obtained leave to return to their own country, rebuild their temple, and re-establish their own worship: it included likewise the reign of Alexander the Great, and the overthrow of the Persian empire.

10. The *sixth* period includes the rise and progress of the four empires which had arisen out of the vast empire of Alexander, and the history of the exploits of the Romans and Carthaginians till the destruction of Carthage about a century and half prior to the birth of Christ.

11. The *seventh* period is occupied in the conquests of the Romans, till their empire had attained its greatest magnitude, and till the time when an end was put to the Roman republic: it includes also the conquest of Britain by Claudius, and the destruction of Jerusalem by Vespasian. It ended with the death of Trajan.

12. The *eighth* period extends from the death of Trajan to the division of the empire under Constantine.

13. The *ninth* period exhibits the decline and miserable end of the western part of the Roman empire: it details important revolutions that occurred in Britain, Italy, France, and Spain.

14. During this period Africa, properly so called, had changed its masters three times: the Vandals had expelled the Romans, and erected an independent kingdom, which was at length overturned by the emperors of Constantinople, and from them it was taken by the Goths, A. D. 620.

15. The *tenth* period is dated from the flight of Mahomet in the year 622: it includes the rise, pro gress, and victories of that conqueror, and the fall of his empire: it relates to the conquests of the Turks and Saracens; the establishment of the pope's temporal power; and it extends to the period of the crusades.

16. The *eleventh* period of history commences with the crusades, and includes all the space intervening from between that time and the present.

QUESTIONS FOR EXAMINATION.

1. Into what does history resolve itself?
2. To what does the first general period refer?
3. In what state were men at this period?
4. What was the state of society then?
5. When did the second period commence, and how far did it extend?
6. What does it include?
7. When did the third period begin, and what did it include?
8. To what did the fourth period extend?
9. What happened during the fifth period?
10. What did the sixth period include?
11. In what is the seventh period occupied, and what does it include?
12. How far does the eighth period extend?
13. What does the ninth period exhibit?
14. What occurred in Africa during that period?
15. Which is the tenth period?
16. When does the eleventh period commence, and what space does it include?

ARITHMETIC.

ITS HISTORY AND UTILITY.

"The first elements of Arithmetic are acquired during our infancy; for when a child gathers as many stones together as suits his fancy, and throws them away, he acquires the first elements of the two capital operations in arithmetic, addition and subtraction."

(*Academy of Sciences and Art—Article, Arithmetic.*)

It is remarked by an able writer upon the history of this science, that "at what time it was introduced into the world cannot be easily determined. History fixes neither the author nor the time." This is no doubt true; but we may nevertheless safely affirm of the four first fundamental principles: viz. addition, subtraction, multiplication, and division, that they have always in a certain degree been practised by different nations.

Numbers, as a science, must in a great measure have depended on the advancement of commerce, because arithmetical calculations, becoming then more necessary, would receive a greater degree of attention. Thus arithmetic is, with much probability, supposed to have been of Tyrian or of Phœnician invention. From Asia it is said to have passed into Egypt; from Egypt arithmetic was transmitted to the Greeks; thence, with its improvements, it proceeded to the Romans; and from the Romans, it has been dispersed over the modern nations of the world. The symbols or characters of numbers and the scale of numerical calculations have been considerably diversified in different ages. The Hebrews and Greeks, and after them the Romans, had recourse to the letters of their alphabet for the representation of numbers. The Mexicans adopted circles for cyphers, and the ancient Peruvians coloured knotted cords, called *quipos.* The Indians are at this time very expert in computing by means of their fingers, and the modern natives of Peru are said, by the different arrangements of their grains of maize, to surpass Europeans, aided by all their rules.

The Arabian or Indian notation, which is now universally practised, was originally derived from the Indians; and was, in the tenth century, brought by the Moors or Saracens from Arabia into Spain. Its improvements principally consist in

its brevity and precision; instead of employing twenty four characters, only nine digits and a cypher are wanted. The symbols also are more simple, more appropriate and determined; and therefore the powers of them are less liable to inaccuracy or confusion. With the symbols too, the scale of numerical calculations has been varied. The first improvement was the introduction of reckoning by tens, which, no doubt, took its rise from the obvious mode of counting by the fingers, as that was customary in the primary calculations of every nation, except the Chinese.

The Greeks, as will be seen in the following lessons, had two methods of marking the advance of numbers: one on the plan which was afterwards adopted by the Romans, and which is still used to distinguish the chapters and sections of books; and in the other, the first nine letters of the alphabet represented the first numbers from 1 to 9, the next nine so many tens, from 10 to 90. The number of hundreds was expressed by other letters, supplying what was wanting either by other marks or characters, or by repeating the letters with different signs in order to describe thousands, tens of thousands, &c.

Upon this mode of computation, the writers in a modern encyclopedia have the following judicious and apposite observations. "The ancient Greeks and Romans would have brought the science of arithmetic to a much greater degree of perfection than they ever did, had they hit upon the method of expressing by ten distinct characters the numbers by which they reckoned. But the idea of a cypher, which can only be introduced into the *decadary system*, and which may be styled the KEY STONE of Arithmetic, seems never to have struck them; and thus, though they reckoned properly enough by tens, yet not having characters proportionate enough to express their numbers, they involved their Arithmetic in a labyrinth of confusion, from which neither a EUCLID, nor an ARCHIMEDES, with all their wonderful mechanical powers, were able to extricate it, for want of this clue. In a word it is to the cypher, in uniform alternation with the nine digits, that the moderns owe the honour of having perfected a science, in which the ancients, with all their great attainments, had made but small progress. And perhaps if all our modern weights and measures were divided and subdivided upon the decadary plan, instead of into fourths, eighths, twelfths, sixteenths, &c. that general uniformity of both, so long wanted, might soon be attained."

About the year of our Lord 200, a new kind of arithmetic, called *sexagesimal*, was invented by Ptolemy. Every unit was

supposed to be divided into 60 parts, and each of these into 60 others, &c. Thus from 1 to 59 were marked in the common way :—then 60 was called a sexagesima, or first sexagesimal integer, and had one single dash over it, as 1′; 60 times 60 was called "sexagesima secunda," and marked 1″, &c.

These methods of calculation are continued by astronomers in the subdivisions of the degrees of circles. The *decuple* or Arabian scale, substitutes *decimal* instead of sexagesimal progression, and by this single process removes the difficulties and embarrassments of the preceding modes. Thus the signs of numbers from 1 to 9 are considered as simple characters, denoting the simple numbers subjoined to the character; the cypher 0, by filling the blanks, denotes the want of a number or unit in that place; and the addition of the columns in a ten-fold ratio, always expressing ten times the former, leads from tens, according to the order in which they stand, in a method at once most luminous and certain.

For decimal parts, we are indebted to Regiomontanus, who about the year 1464 published his book of Triangular Canons. Dr. Wallis invented the use of circulating decimals, and the arithmetic of infinities; but the last, and with regard to extensive application, the greatest improvement which the art of computation ever received, was from the invention of logarithms, the honour of which is due to John Napier, baron of Merchiston in Scotland, who published his discovery about the beginning of the seventeenth century. Mr. Henry Briggs followed Baron Napier on the same subject.

Arithmetic may now be considered as having advanced to a degree of perfection which, in former times, could scarcely have been conceived, and to be one of those few sciences which have little room for improvement.

LESSON THE FIRST.

1. Arithmetic is the science of numbers, and teaches the art of computing by them.

2. The Greeks made use of the letters of their alphabet to represent their numbers. The Romans followed the same method; and besides characters for each rank of classes, they introduced others for five, fifty, and five-hundred, &c.

Ex.	One	five	ten	fifty	one hundred.
	I	V	X	L	C

five hundred	one thousand
D	M

3. Any number may be represented by repeating and combining the letters: thus XX stands for two tens, or twenty: CCC for three hundred, and so on.

4. When a numeral letter is placed *after* one of greater value, their values are added: thus XII stands for ten and two, or twelve: LXXVII for seventy-seven: MDCLXVI, for one thousand six hundred and sixty-six.

5. When a numeral letter is placed *before* one of greater value, the value of the less is taken from that of the greater: thus IX stands for ten less one, or nine: XL for fifty less ten, or forty: XC one hundred less ten, or ninety.

6. The method of notation that we now use is taken from the Arabians, and the characters by which all the operations of common arithmetic are performed, are, 1, 2, 3, 4, 5, 6, 7, 8, 9, 0; the first nine are called significant figures.

7. Significant figures, when placed singly, denote the simple numbers subjoined to the characters.

8. When several significant numbers are placed together, the first or right hand figure only is to be taken for its simple value: the second signifies so many tens, the third so many hundreds, and so on.

Ex.—In 7777, the right hand figure stands for 7 only, the next stands for 70, the third for 700, and the fourth for 7000, so that the whole reads seven thousand, seven hundred, and seventy-seven.

9. The cipher in any place denotes the want of a number in that place, thus 50 denotes five tens, and no unit or simple number: so 304 denotes three hundred and four, there being no significant figure in the tens place.

10. The whole art of arithmetic is comprehended in various modifications of the four rules, Addition; Subtraction; Multiplication; and Division.

11. *Addition* is that operation by which several numbers or sums are collected into one total.

				£.	s.	d.
Ex. (1.)	583		(2.)	48	14	6
	487			91	10	10
	965			14	9	$0\frac{1}{2}$
	321			26	19	$9\frac{1}{4}$
Total	2356			£181	14	$1\frac{3}{4}$

12. *Subtraction* is the operation by which we take a less number, or sum, from a greater, and find their difference.

		£.	s.	d.
Examples	9876	581	13	$9\frac{1}{2}$
	4937	298	19	$8\frac{3}{4}$
Difference	4939	£282	14	$0\frac{3}{4}$

13. *Multiplication* is a compendious mode of addition, and teacheth to find the amount of any given number, by repeating it any proposed number of times.

		£.	s.	d.	
Example	5876	34	6	$9\frac{1}{2}$	$\times 35 = 7 \times 5$
	49			7	
	52884	240	7	$6\frac{1}{2}$	
	23504			5	
Product	287924	£1201	17	$8\frac{1}{2}$	

14. *Division* teacheth to find how often one number is contained in another of the same denomination, and thereby performs the work of many subtractions.

		£.	s.	d.
Example.	8) 76543	6) 865	14	9
	9567—7	£144	5	$9\frac{1}{2}$

QUESTIONS FOR EXAMINATION.

1. What is arithmetic?
2. What did the Greeks and Romans use f numbers?
3. How were numbers represented by the Roman letters?
4. In what way was the addition of a number performed?
5. How was a number taken away by the Roman method?
6. From whom is derived the modern method of notation, and what are the characters used?
7. What do the significant figures denote when placed singly?
8. How are they reckoned when placed together?
Explain by the example.
9. What does the cipher denote?
10. In what is the whole art of arithmetic comprehended?
11. What is addition?
Explain by the examples.
12. What is subtraction?
Explain by the examples?
13. What is multiplication, and what does it teach?
Explain by the examples.
14. What is division, and what does it teach?
Explain by the examples.

LESSON THE SECOND.

1. *Reduction* teaches to bring numbers from one denomination to another, without changing their value: it is used to simplify the operations in other rules.

Example.—If I wish to know how many half-crowns there are in £1. 12*s*. 6*d*. I reduce the given sum, and also the half-crown into pence, or into sixpences, and divide the greater by the less: thus there are 5 sixpences in half a crown, and 65 sixpences in £1. 12*s*. 6*d*. and 65 divided by 5 give 13 for the answer, that is, there are 13 half-crowns in £1. 12*s*. 6*d*.

2. In reduction all great names are brought into lesser by multiplication: and less names are brought into greater by division.

Example.—Pounds are brought into pence by multiplying by 20 and by 12: and pence are brought into guineas by dividing by 12 and 21.

3. *Proportion*, or as it is often denominated, the golden rule of proportion, on account of its general application to questions in mathematics and arithmetic, is divided into direct, inverse, and compound proportion.

4. *Direct proportion*, or the rule of three direct, is employed in finding, from three given numbers, a fourth, which shall have the same relation to the third, as the second has to the first.

Example.—If the three numbers be 2, 6, 10, then the fourth will be 30, because 30 has the same proportion to 10 that 6 has to 2.

5. The fourth number is found by multiplying the second and third together, and dividing by the first.

6. *Inverse proportion*, or the rule of three inverse, teacheth from three given numbers how to find a fourth, which fourth shall have the same relation to the second, as the first has to the third.

Example.—If the three numbers be 15, 9, 5, then the fourth will be 27.

7. The fourth number is found by multiplying the first and second numbers together, and dividing by the third; thus $\frac{15 \times 9}{5} = 27$.

8. *Compound proportion*, commonly called in arithmetical books the double rule of three, or rule of five, is a rule in which more than three terms are given to find another dependant upon them.

Example.—If 8 men can reap 40 acres in 7 days, how many acres can be reaped by 24 men in 28 days.

Men	Days	Acres	Men	Days	
8	7	40	24	28	Ans. $\frac{24 \times 28 \times 40}{8 \times 7} = 480$ acres.

The same might be found by two statements of single proportion thus:

Men 8	Acres 40	Men 24	Acres 120
Days 7	Acres 120	Days 28	Acres 480 as

before.

Explanation.—Here it is first found that if 8 men can reap 40 acres in a certain time, 24 men could in

the same time reap 120: it is then found that if in this certain time, viz. 7 days, 120 acres can be reaped, how many might be reaped in 28 days.

9. *Practice* is a compendious method of working the "rule of three direct," that is, such questions as have unity for the first term.

Example.—If one pound of tea cost 6*s*. 9*d*. what will 28lb. cost: here I multiply the price of one lb. by the number of pounds: 6*s*. 9*d*. × 28 or 4 × 7 = £9. 9*s*.

10. *Fractions*, are, as the term denotes, broken parts of a whole number or unit, and they are divided into vulgar and decimal, both of which are worked by the four fundamental rules, addition, subtraction, multiplication, and division.

11. In vulgar fractions we suppose unity divided into several equal parts, one or more of these is called a fraction, and is represented by placing one number in a smaller character above a line called the numerator, and another under it, called the denominator: as $\frac{3}{5}$, $\frac{5}{8}$, $\frac{8}{12}$, &c.

ILLUSTRATION.—In the first of these fractions the unit is supposed to consist of 5 equal parts, and the fraction to be equal to three-fifth parts; that is, if the unit be a pound sterling, then each fifth part will be equal to 4*s*. and the fraction three-fifths will be equal to 12*s*. In the second fraction the unit, say 1*s*. is supposed to be divided into 8 parts, and $\frac{5}{8}$ths is equal to 7½*d*.

12 A decimal is a fraction, having always 10, or some power of ten for its denominator, which is understood and not expressed.

Example.—The fractions $\frac{5}{10}$, $\frac{75}{100}$, $\frac{784}{1000}$, are expressed in decimals by the numerators, only with dots or commas before them; as, .5, .75, .784; if the decimal five be part of a pound or shilling, its value will be five-tenths, or one-half of the like sums, or 10*s*. or 6*d*. If 75 be the decimal of a hundred-weight, it will be found equal to 84lb. by multiplying the decimal by the number of pounds in the cwt. and striking off as many figures to

the right of the product as there are decimal figures in the fraction: thus $.75 \times 112 = 84.00$.

QUESTIONS FOR EXAMINATION.

1. What is reduction, and for what purposes is it used?
Explain by the example.
2. How is reduction performed?
Give the examples.
3. What is proportion, and how is it distinguished?
4. What is meant by direct proportion?
Give the example.
5. How is the fourth number found?
6. What is meant by inverse proportion?
Give the example.
7. How is the fourth number found?
8. What is compound proportion?
What is the example?
How is the same result obtained by two statements?
Give the explanation.
9. What is practice?
Give the example.
10. What are fractions?
11. Explain what is meant by vulgar fractions.
Give the illustration.
12. What do you mean by a decimal fraction?
Give the example.

ALGEBRA.

ITS DEFINITION, ORIGIN, AND HISTORY.—WORKS OF INDIAN ALGEBRA.

"The present language of Algebra is the most perfect instrument of thought which has yet been contrived." *Eclectic Review*, 1827.

ALGEBRA is an Arabic word of uncertain etymology. It is probably derived from *al* and *geber*, which signifies the reduction of fractions to a whole number. It may be defined to be a peculiar kind of arithmetic, which takes the quantity sought as if it were granted, and by means of one or more quantities given, proceeds by consequence, till the quantity

at first only supposed to be known, or at least some power thereof, is found to be equal to some quantity or quantities which are known; and consequently is itself known.

A quantity which can be measured, and is the object of mathematics, is of two kinds, number and extension. The former is treated of in arithmetic, the latter in geometry. Numbers are ranged in a scale, by the continual repetition of some one number, which is called the *root;* and in consequence of this order, they are conveniently expressed in words, and denoted by characters. Investigations by common arithmetic are greatly limited from the want of characters to express the quantities that are unknown, and their different relations to one another, and to such as are known. Hence letters, and other convenient symbols, have been introduced to supply this defect; and thus gradually has arisen the science of *Algebra,* properly called Universal Arithmetic. In the common arithmetic, too, the given numbers disappear in the course of the operation, so that general rules can seldom be derived from it; but in algebra, the known quantities, as well as the unknown, may be expressed by letters, which, through the whole operation, retain their original form; and hence may be deduced not only general rules for like cases, but the dependence of the several quantities concerned, and likewise the determination of a problem, without exhibiting which, it is not completely resolved. This general method of expressing quantities also, and the general reasonings concerning their connections, which may be founded on it, have rendered this science not less useful in the demonstration of theorems, than in the resolution of problems. If geometrical quantities be supposed to be divided into equal parts, their relations in respect of magnitude, or their proportions, may be expressed by numbers; one of these equal parts being denoted by the unit. Arithmetic, however, is used in expressing only the conclusions of geometrical propositions; and it is by algebra that the bounds and application of geometry have been of late so far extended. The proper objects of mathematical science are number and extension; but mathematical enquiries may be instituted also concerning any physical quantities, that are capable of being measured or expressed by numbers and extended magnitudes; and as the application of algebra may be equally universal, it has been properly designated the science of quantity in general.

Much controversy and disputation has been expended upon the history of the progress and improvements of algebra.

This has been induced by the partiality and prejudices which are natural to all nations, and by the want of a closer examination of the works of the older authors on this subject. From these causes it has happened that the improvements made by the writers of one nation have been ascribed to those of another; and the discoveries of an earlier author to some one of much later date; add to this also, that the peculiar methods of many authors have been described so little in detail, that our information derived from such histories is but very imperfect, and amounts only to general and vague ideas of the true state of the arts. The earliest treatise on algebra, which has come down to the present time, is that of Diophantus, of Alexandria in Egypt, who flourished in the middle of the fourth century after Christ, and wrote a work on this subject in the Greek language, consisting originally of thirteen books, though unfortunately for the interest of science, only the first six are now extant.

Other works on the subject, of a more easy and elementary kind, must, however, have existed long before the time of Diophantus, since he nowhere treats of the leading rules, as a writer in the infancy of the art would have done. Whether we are indebted for this admirable invention to the genius of the Greeks, as has hitherto been thought, or to that of some other ancient nation, cannot at this distance of time be easily ascertained; though, from the information which for more than a century past has been gradually obtained through our intercourse with the East, there are strong reasons for believing that algebra, as well as our common system of arithmetic, originated among the Hindoos, or natives of India, who are known to possess some valuable works on the subject, containing rules and principles apparently not derived from any foreign source.

Among the fragments of Eastern science with which the learning and zeal of our countrymen in India have enriched the literature of the west, is four different Indian treatises, in Sanscrit verse, on the arithmetic, algebra, and geometry of Hindostan, translated by Henry Thomas Colebrooke, Esq. F.R.S. Two of these, the *Lilavati* and *Vija Ganita*, are the works of BHASCARA ACHARYA; the first on arithmetic, the second on algebra. The other two books are still more ancient, and were composed by a mathematician of the name of BRAHMEGUPTA. These, like most of the mathematical writings of the Hindoos, make parts of systems of astronomy.

The time of BHASCARA is fixed with great precision

by his own testimony, and by corresponding circumstances, to a date that answers to about the year 1150 of the Christian era. The age of BRAHMEGUPTA is considerably more remote, and his works are extremely rare. The age in which he lived is fixed by Mr. Colebrooke, after a display of surprising industry and zeal, with great probability, from a variety of concurring circumstances, and particularly from the position which he assigns in his astronomy to the solstitial points, to the sixth, or the beginning of the seventh century of the Christian era, and antecedent therefore to the first dawn of the sciences in Arabia. At the same time it is observed, that even BRAHMEGUPTA'S treatise, is not by any means the earliest work known to have been written in India on the subject of algebra. GANESA, the most eminent of the scholiasts and commentators of BHASCARA, quotes a passage from ARYA-BHATTA, on the subject of algebra, containing a very refined artifice for the solution of indeterminate problems, which is known in *Sanscrit*, by the name of *Cuttaca*. Arya-Bhatta is, indeed, regarded by the Indians as the most ancient uninspired writer on the science of astronomy; and by a variety of arguments, which Mr. Colebrooke's intimate acquaintance with the literature and the history of that country has furnished, he makes it appear, that this algebraist wrote as far back as the fifth century of the Christian era, and perhaps, in an earlier age. Hence it follows, that he is nearly as ancient as the Grecian algebraist DIOPHANTUS, supposed as I have said, to have flourished in the middle of the fourth century, or about the year 360. Mr. Colebrooke goes on to remark, that admitting the Hindoo and Alexandrian authors to be nearly equally ancient, it must be conceded in favour of the former, that he was the more advanced in the science, since he appears to have been in possession of the resolution of equations, involving several unknown quantities, which it is not clear, nor fairly presumable, that DIOPHANTUS knew. Mr. Colebrooke seems willing to stop here, without carrying back the origin of the algebra of the Hindoos to a more remote period. I may observe, however, that though no precise, or even traditionary knowledge, concerning that science can be carried to a more remote age, it is impossible to doubt of its having existed long before, and having passed by many steps to the condition it had then attained. It is very generally acknowledged that DIOPHANTUS cannot have been himself the inventor of all the rules and methods which he delivers. Much less is ARYA-BHATTA to be held the sole inventor of a system that is still

more perfect than that of DIOPHANTUS. Before an author could think of embodying a treatise of algebra in the heart of a system of astronomy, and turning the researches of the one science to the purposes of the other, both must be in such a state of advancement, as the lapse of several ages, and many repeated efforts of invention, were required to produce.

I will take a brief and summary view of one of these Hindoo treatises. The *Lilavati* treats of arithmetic, and contains not only the common rules of that science (there reckoned eight), but the application of those rules to a variety of questions on interest, barter, mixtures, combinations and permutations, indeterminate problems; and lastly, the mensuration of surfaces and solids. All this is done in verse; and the language, even when it is the most technical, seems often to be highly figurative. The question is usually propounded with enigmatical conciseness; the rule for the computation is next given in terms somewhat less obscure; but it is not till the example which comes in the third place has been studied, that all ambiguity is removed. No demonstration nor reasoning, either analytical or synthetical, is subjoined; but on examination, the rules are not only found to be exact, but to be nearly as simple as they can be made, even in the present state of analytical investigation. The numerical results are readily deduced; and if we compare them with the earliest specimens of calculation that have come to us even from Greece itself, the advantages of the decimal notation, and the alogorithm arising from it, will be placed in a striking light.

But the peculiar character of the book, and of the Oriental style which often unites so ill with the severity of arithmetical computation, will be best understood by an extract or two from the work itself. It begins thus:

"Having bowed to the Deity, whose head is like an elephant's, whose feet are adored by gods; who when called to mind, restores his votaries from embarrassment, and bestows happiness upon his worshippers; I propound this easy process of computation, delightful by its elegance, perspicuous with words concise, soft and correct, and pleasant to the learned."

From this lofty and pious exordium, the author immediately descends to the common business of calculation, and enters on the explanation of such terms as are naturally placed at the beginning of a book of practical arithmetic, viz. the names of numbers, tables of coins, weights, measures, &c. In the table of measures he makes the same

attempt to fix on a natural standard of linear extent that was anciently made in our own country. Eight breadths of a barley-corn are said to make a finger or an inch; and it is added in the commentary of GANESA, that the length of three grains of rice is held to be equal to the breadth of eight grains of barley. Much refinement, indeed, was not necessary to perceive the value of a standard which the highest improvements, both in art and in science have been found necessary to construct. The definitions are given in the form of an introduction, and are followed by an invocation: "Salutation to GANESA, resplendent as a blue and spotless lotus, and delighting in the tremulous motion of the dark serpent, which is continually twining within his throat." The rules of arithmetic are then delivered in verse, and addressed to *Lilavati*, a young and charming female, who appears to be receiving the instructions of the author, and to whom the examples of the rules are usually proposed as questions to be resolved. The rules explained as elementary are, addition, subtraction, multiplication, division, squaring of numbers, cubing of numbers, extraction of the square root, extraction of the cube root.

In the beginning of a new chapter, the third, an operation is treated of, which is called *inversion;* and nothing can be more unlike the scientific language of Europe, than the terms in which this rule is delivered.

"To investigate a quantity, one being given, make the divisor a multiplier, and the multiplier a divisor; the square a root, and the root a square: turn the negative into positive, and the positive into negative. If a quantity was diminished by its own proportional part, let the denominator, being increased or diminished by its numerator, become the denominator, and the numerator remain unchanged, and then proceed with the other operations of inversion, as above directed."

From all that is here said, one can hardly guess either at what is required, or what is directed to be done. We learn something more precise, however, from the question that the instructor puts to his fair pupil.

"Pretty girl with tremulous eyes, if thou know the correct method of *inversion*, tell me what is the number which multiplied by 3, and added to three quarters of the product, and divided by 7, and reduced by subtraction of a third part of the quotient, and then multiplied into itself, and having 52 subtracted from the product, and the square root of the

remainder extracted, and 8 added, and the sum divided by 10, yields 2?"

The numercial statement is next given, but not with much precision; and it is added, that by applying the rule, 28 will be found to be the number sought. "This," says Mr. Colebrooke, "is true; and if we put the question into an equation, according to the preceding enunciation, we shall find a pure quadratic, from which the number sought comes out equal to 28: the steps of the calculation being nearly the same that are enjoined in the preceding rule. Thus:

If x be the unknown quantity, then $3x + \frac{3.3x}{4} = \frac{21x}{4}$; and this divided by 7, is $\frac{3x}{4}$. Now $\frac{3x}{4} - \frac{x}{4} = \frac{x}{2}$. The square of this last, minus 52, is $\frac{x^2}{4} - 52$, and therefore $\frac{(\frac{x^2}{4} - 52)^{\frac{1}{2}} + 8}{10} = 2$, or $(\frac{x^2}{4} - 52)^{\frac{1}{2}} = 12$. Whence $\frac{x^2}{4} - 52 = 144$, $\frac{x^2}{4} = 196$, $\frac{x}{4} = 14$, and $x = 28$. ———"

But not to dwell longer upon this part of the subject, and to terminate what may be considered a digression and a departure from strict method, though a pardonable one, I observe that it is well known, that in whatever age or country algebra was first invented, both the name and the science was first made known to us, about the end of the eleventh century, by the Arabians, or Moors, who were settled in Spain. Algebra was introduced into Italy by Leonardus Bonacci, commonly called Leonard of Pisa, an Italian merchant, in the beginning of the thirteenth century: and Mr. Colebrooke has some deeply interesting notes, in the work from which I have already quoted, upon its progress, which he traces with great skill, and the powerful aid of a combination of scientific and literary information of an extraordinary description. After this many manuscript treatises appeared in Italy; but the first printed works on this subject are those of Lucas Pacciolus, or Lucas de Burgos, in the years 1470, 1481, and 1494: hitherto the science had advanced no further than quadratic equations; the passage, indeed, to the higher orders was a matter of considerable difficulty. It was, however, by subsequent mathematicians advanced to the solution of cubic equations in the year 1505. But it is chiefly

to the celebrated Vieta, whose algebraic works were written about the year 1600, though not printed till after his death, which happened in 1603, that we are indebted for having first generalized the algorithm of the science, and enriched it, far beyond what his predecessors had done, by many new discoveries. Stifelius, about 1500, first introduced the capital letters for unknown quantities; but Vieta employed the same letters to denote all quantities, whether known or unknown. To Vieta we are likewise indebted for the method of extracting the roots of equations by approximation, which has been since greatly improved by Rapson, Halley, Maclaurin, Simpson, and others.

Next after Vieta, may be mentioned Albert Girard, an ingenious mathematician of the low countries. Among the most distinguished analysts of this period may be reckoned our countryman, the celebrated Harriot, who, in his Artis Analyticæ Praxis, published by his friend Walter Warner, first introduced the use of the small letters, *a*, *b*, *c*, &c. of the alphabet, using the consonants for known, and the vowels for unknown quantities. He likewise farther shewed how the higher orders of equations may be produced by the continued multiplication of those of the first.

The elements of the art were compiled and published by Viersey in 1671, in which specious arithmetic and the nature of equations are largely explained and illustrated by a variety of examples. Sir Isaac Newton's Arithmetica Universalis was published in 1707, which abounds with useful and important instruction; and since his time we have had a great number of excellent treatises on the subject, from almost any of which the science may with very little difficulty be learned. The elementary works most useful for beginners are those of Clairant, Lacroix, Maclaurin, Simpson, Emerson, Wood, Bonnycastle, and Nicholson.

LESSON THE FIRST.

1. Algebra is a method of performing the calculations of all sorts of quantities by means of general signs or characters.

Illustration.—At first, numbers and things were expressed by their names at full length, but afterwards these were abridged, and the initials of the words were

used instead of them: then the letters of the alphabet came to be employed as general representatives of all kinds of quantities.

2. Algebra has been called "Specious Arithmetic," on account of the species or letters of the alphabet used; and it is denominated by Sir Isaac Newton, "Universal Arithmetic," from the manner in which it performs all arithmetical operations by general signs.

Illustration.—Every figure or arithmetical character has a determinate and individual value, thus the figures 5, 7, 9, &c. always represent the same numbers: but algebraical characters are general and independent of any particular signification.

3. In algebra some quantities are assumed as known, and others as unknown; the known quantities are usually represented by the early letters of the alphabet, and the unknown ones by the final letters.

Example.—a, b, c, d, e, &c. are commonly put for known quantities, and x, y, z, &c. for the unknown and indeterminate quantities: thus if $a + x = 12$, and it is known that a is equal 5, then it is found that $x = 7$.

4. The signs $+$, $-$, $\times$, $\div$, $=$, are used in algebra as in arithmetic.

Examples.—$a + b$ signifies that a and b are added together; $x - y$ shews that y is to be subtracted from x: $a \times b \times c$ shews that the quantities represented by a, b, c, are to be multiplied together, and $a \times b \times c$ signifies the same as $a\,b\,c$; $a \div b$ shews that a is to be divided by b, the same is represented by $\frac{a}{b}$.

5. a^2, a^3, a^4; x^2, x^3, x^4, are the squares, and the third and fourth powers of a and x.

6. The mark $\surd$ or $\sqrt{}$ is the sign of the square root, and with a small 3, 4, 5, &c. before it, the roots of the third, fourth, and fifth powers are denoted.

Examples.—$\sqrt{x}$ is the square root of x; $\sqrt[3]{x}$ is the cube root of x: $\sqrt[4]{x}$, $\sqrt[5]{x}$ are the roots of the fourth and fifth powers.

7. Like quantities are those which consist of the same letters or powers: thus $3a$, $5a$, a, are like quantities; so are $4\,a^2b$, $2\,a^2b$, a^2b.

8. Unlike quantities are those which consist of different letters or powers: thus a and x are unlike quantities: so also are a and a^2: $4\,a$ and $4\,a^2$: $5\,a\,b$, $5\,a\,c$.

9. Like signs are either all positive + or all negative —: and unlike signs are when some are positive, and some negative.

10. Co-efficients are such numbers as are put before letters, or quantities, into which letters or quantities they are supposed to be multiplied: thus in the quantity $5\,a\,x$, 5 is the co-efficient which is supposed to be multiplied into $a\,x$.

QUESTIONS FOR EXAMINATION.

1. What is algebra?
Give the illustration.
2. How has algebra been denominated, and why?
What is the illustration?
4. What is meant by known and unknown quantities, and how are they represented?
What is the example?
4. What are the signs used in algebra?
Give the examples.
5. How are the squares and other higher powers of a and x represented?
6. How are the square and other roots of quantities represented?
Write down the examples.
7. What are like quantities?
8. What are unlike quantities?
9. What are like or unlike signs?
10. What is meant by co-efficients?

LESSON THE SECOND.

1. The fundamental operations in algebra are performed by addition, subtraction, multiplication, and division.

2. In addition there are three distinct cases, viz. to add terms that are like and have like signs:—to add terms that are like and have unlike signs:—to add terms that are unlike.

3. To add terms that are like and have like signs: "Add together the co-efficients, to their sum prefix the common sign, and subjoin the common letter or letters."

Example.—		
	$4\,abc$	$3\,b + 2\,c - 4\,d$
	$8\,abc$	$b + 6\,c - 3\,d$
	abc	$9\,b + c - 5\,d$
	$13\,abc$	$13\,b + 9\,c - 12\,d$

ILLUSTRATION.—When there is no sign before a quantity, as in the first example, + is understood: when there is no co-efficient unit is understood, therefore in adding the first example we say 1 and 8 and 4 = 13.

4. To add terms that are like, but have unlike signs, "Subtract the lesser co-efficient from the greater, and prefix the sign of the greater to the remainder, and subjoin the common letter or letters."

Examples.			
	$-5\,x$	$-7\,x\,y$	$-4\,a\,z$
	$+6\,x$	$+4\,x\,y$	$+9\,a\,z$
			$-5\,a\,z$
	$+x$	$-3\,x\,y$	*

ILLUSTRATION.—In the first example we take the $5\,x$ from the $6\,x$, and $1\,x$ is the remainder, but the co-efficient 1 is understood and never expressed: in the second example we take + 4 from — 7, and the remainder is — 3: in the third example we have + 9, and (when the 4 and 5 are added) — 9, which destroy one another, and the answer is 0.

5. To add terms that are unlike, "Set them all down one after another, with their signs and co-efficients prefixed: thus $2\,b + 9\,x - 7\,z - 6\,x^2$."

6. To subtract quantities; "Change the sign of the quantity to be subtracted into the contrary sign, and

then add it, so changed, to the quantity from which it was to be subtracted."

Ex.
$$\begin{array}{r} +5x \\ +2x \\ \hline +3x \\ \hline \end{array} \qquad \begin{array}{r} +8z \\ -4z \\ \hline +12z \\ \hline \end{array} \qquad \begin{array}{l} +6ab-10xy \\ +4ab+\ \ 5xy-9 \\ \hline +2ab-15xy+9 \\ \hline \end{array}$$

7. In multiplication, when the signs of the two terms to be multiplied are like, the sign of the product is +, but when they are unlike, the sign of the product is —.

8. To multiply two terms into one another, "Find the sign of the product: after it place the product of the numeral co-efficients, and set down the letters one after another."

Ex. $4a \times 5b = 20ab.$
$-8a \times -9xy = +72axy.$
$+5bc \times -4ad = -20abcd.$

9. To multiply compound quantities, "Multiply every term of the multiplicand by all the terms of the multiplier, one after another, and then collect the products into one sum."

Examples.—Multiply $\overline{a+b}$ by $\overline{a-b}$, and $\overline{a+b-x}$ by $\overline{a-b}$.

$$\begin{array}{l} \quad a+b \\ \quad a-b \\ \hline a^2+ab \\ \quad -ab-b^2 \\ \hline a^2 \ * \quad -b^2 \\ \hline \end{array} \qquad \begin{array}{l} \quad a+b-x \\ \quad a-b \\ \hline a^2+ab-ax \\ \quad -ab-b^2+bx \\ \hline a^2 \ * \quad -ax-b^2+bx \\ \hline \end{array}$$

Explanation.—In the first example + and — ab destroy one another; and the answer is a^2-b^2: suppose $a=4$, and $b=3$, then in figures it will be $7 \times 1 = 7$, which is equal $4^2-3^2=16-9=7$; or suppose $a=9$ and $b=5$, then $a^2-b^2=81-25=56 = 14 \times 4$. In the second example $+ab$ and $-ab$ destroy one another, and the other quantities being unlike, they must be set one after another. Suppose

$a = 6$, $b = 4$, and $x = 2$, then $a + b - x = 8$ and $a - b = 2$, consequently $8 \times 2 = a^2 - ax - b^2 + bx = 36 - 12 - 16 + 8 = 16$.

10. Division is the converse of multiplication. When the divisor and dividend are both simple quantities, "Set the terms down as in the division of numbers, either the divisor before the dividend, or below it like a fraction, then abbreviate these terms as much as possible, by cancelling all the letters common to both, and dividing one co-efficient by the other."

Ex.—Divide $15\,a\,x$ by $5\,a$, and $28\,a\,b\,x\,y$ by $7\,a\,b$.

$$5\,a)\ 15\,a\,x \qquad \text{Answer } 3\,x \qquad\qquad \frac{28\,a\,b\,x\,y}{7\,a\,b} = 4\,x\,y \text{ answer.}$$

11. When the dividend is a compound quantity, "Divide every term of the dividend by the divisor."

Ex.—Divide $25\,a\,x\,b + 30\,a\,x\,z - 5\,a\,x\,y^2$ by $5\,a\,x$.

$$\frac{25\,a\,x\,b + 30\,a\,x\,z - 5\,a\,x\,y^2}{5\,a\,x} = 5\,b + 6\,z - y.$$

12. When the divisor and dividend are both compound quantities, "Set them down as in division of numbers: divide the first term of the dividend by the first term of the divisor, and place the result in the quotient: then multiply the whole divisor by the term thus found, and subtract the result from the dividend: bring down the other terms, and proceed as before.

Example.—Divide $a^4 + 4\,a^3\,b + 6\,a\,b + 4\,a\,b\,3 + b^4$ by $a + b$.

$$\begin{array}{llllll}
a + b) & a^4 + 4\,a^3\,b & + 6\,a^2\,b^2 & + 4\,a\,b^3 & + b^4 & (a^3 + 3\,a^2\,b + 3\,a\,b^2 + b^3 \\
 & a^4 + a^3\,b & & & & \\
\hline
 & * + 3\,a^3\,b & + 6\,a^2\,b^2 & & & \\
 & 3\,a^3\,b & + 3\,a^2\,b^2 & & & \\
\hline
 & * & + 3\,a^2\,b^2 & + 4\,a\,b^3 & & \\
 & & + 3\,a^2\,b^2 & + 3\,a\,b^3 & & \\
\hline
 & & * & a\,b^3 & + b^4 & \\
 & & & a\,b^3 & + b^4 & \\
\hline
 & & & * & * &
\end{array}$$

13. An equation is a proposition asserting the equality of two quantities, which is expressed by placing the sign $=$ between them; thus $36d. = 3s.$

14. A simple equation is that which contains only one power of the unknown quantity; thus $a + b = x$ is a simple equation.

Example.—(1.) Suppose $x + y = 12$ and $x - y = 8$, to find the value of x and y.

$$\begin{array}{rl} x + y &= 12 \\ x - y &= \ \ 8 \\ \hline 2x \quad &= 20 \\ x \quad &= 10 \\ y \quad &= \ \ 2 \end{array}$$

Explanation.—Having two unknown quantities I must get rid of one of them by addition or subtraction: I get rid of the y by addition, and find that $2x = 20$ of course $x = 10$, but $x + y = 12$, therefore y must be equal to 2.

(2.) What two numbers are those whose sum 45 and difference 9, make x and y the unknown numbers then.

$$\begin{array}{rl} x + y &= 45 \\ x - y &= \ \ 9 \\ \hline 2x \quad &= 54 \\ x \quad &= 27 \\ y \quad &= 18 \end{array}$$

QUESTIONS FOR EXAMINATION.

1. How are the fundamental operations in algebra performed?
2. How many cases are there in addition, and what are they?
3. What is the rule in addition when the terms are like, and have like signs?

Work the examples.

How is the operation illustrated?

4. What is the rule when the terms are like, but have unlike signs?

Work the examples.

How is the operation illustrated?

5. How do you add terms that are unlike?

6. What is the rule for subtraction?
Work the examples.
7. What is the rule respecting the signs in multiplication?
8. How do you multiply two terms into one another?
Work the examples.
9. How do you multiply compound quantities?
Work the examples.
Give the explanation.
10. What is division, and what is the rule when the divisor and dividend are simple quantities?
Work the examples.
11. What is the rule when the dividend is a compound quantity?
Work the examples.
12. What is the rule when the divisor and dividend are both compound quantities?
Work the example.
13. What is an equation?
14. What is a simple equation?
Work the first example and give the explanation.
Work the second example.

GEOMETRY.

ON MATHEMATICS.

"If a man's wits be wandering let him study mathematics; for in demonstrations, if his wit be called away never so little, he must begin again."—*Bacon.*

The term mathematics is derived from a Greek word which primarily signifies any discipline or learning. It came in course of time to be limited to one particular description of learning; much in the same manner, and for a similar reason, as the English term learning, has been appropriated to classical knowledge, or the study and acquisition of the dead languages; and it at present denotes that science which teaches or contemplates whatever is capable of being numbered or measured, in so far as computable or measureable; and accordingly is subdivided into arithmetic, which has number for its object, and geometry, which treats of magnitude.

"It is not possible," says an eloquent writer in the London Encyclopædia," that a single word should be descriptive of

any complex object presented to the mind, whether that object exist in nature independently of the mind, or be merely one of its own inventions. Hence the term mathematics cannot be taken as a definition, nor can the definitions which have been attempted for it be regarded as any thing more than approximations to accurate indications. If, for example, we say mathematics is that science which contemplates whatever is capable of being numbered or measured, or that it is the science of quantity, or a science that considers magnitudes, either as computable or measureable, all these and similar attempts at definition, are essentially faulty, because they are not sufficiently definite and comprehensive. It would perhaps be a nearer approach to accuracy of definition, or rather indication to say, *mathematics is the art of computation and measurement*. But this also is defective. The term art, however, is rather more appropriate than the term science; though neither the one nor the other is sufficient of itself for the purpose; for both art and science are necessarily included. Mathematics is neither an art nor a science, but the union of both. We are accustomed to hear of mathematical sciences, knowledge, and learning; we never hear, however, of mathematical art; and the expression no doubt seems strange. But this very circumstance proves the importance of our attempt to awaken attention to what may in itself seem of no consequence. We are the unconscious slaves of habit or custom; and the established usage of language is one of the last species of bondage, which even a philosophic understanding completely shakes off."

Mathematics are commonly distinguished into pure and speculative, which consider quantity abstractedly; and mixed, which treat of magnitude as subsisting in material bodies, and consequently are interwoven everywhere with physical considerations. Mixed mathematics are very comprehensive, since to them may be referred astronomy, optics, geography, hydrography, hydrostatics, mechanics, fortification, navigation, &c. &c.

Pure mathematics have one peculiar and distinguishing advantage, that they occasion no disputes among wrangling disputants, as in other branches of knowledge; and the reason is, because the definitions of the terms are premised, and every body that reads a proposition has the same idea of every part of it. Hence it is easy to put an end to all mathematical controversies, by shewing either that our adversary has not stuck to his definitions, or has not laid down true premises; or else that he has drawn false conclusions

from true principles; and in case we are able to do neither of these, we must acknowledge the truth of what he has proved.

It is true that in mixed mathematics when we reason mathematically upon physical subjects, we cannot give such just definitions as the geometricians; we must therefore rest content with descriptions, and they will be of the same use as definitions, provided we are consistent with ourselves, and always mean the same thing by those terms we have once explained.

The term geometry literally and primarily signifies measuring of the earth, as it was the necessity of measuring the land that first gave occasion to contemplate the principles and rules of this art, which has since been extended to numberless other speculations; insomuch, that together with arithmetic, geometry, as I have already observed, forms now the chief foundation of all mathematics.

Herodotus ascribes the invention of geometry to the Egyptians, and asserts that the annual inundations of the Nile gave occasion to it; for those waters bearing away the bounds and landmarks of estates and farms, covering the face of the ground uniformly with mud, the people, he says, were obliged every year to distinguish and lay out their lands by the consideration of their figure and quantity, and thus by experience and habit they formed a method or art which was the origin of geometry. A further contemplation of the draughts of figures of fields, thus laid down and plotted in proportion, might naturally lead them to the discovery of some of their excellent and wonderful properties; which speculation continually improving, the art continually gained ground, and made advances more and more towards perfection.

LESSON THE FIRST.

1. Geometry is the science of local extension, as of lines, surfaces, and solids, with that of ratios.

2. The term geometry literally signifies measuring the earth, to which it was first applicable; but it has long since been regarded as the foundation of all mathematical knowledge.

3. The invention of geometry was occasioned by the inundations of the Nile, which every year washed away

the boundaries of lands, covered their surface with mud, and obliged the proprietors to lay new claims, by the consideration of the figure and extent of their property.

4. Geometry is distinguished into theoretical and practical.

5. Theoretical or speculative geometry treats of the various properties and relations in magnitudes, demonstrating theorems, &c.

6. Practical geometry is that which applies those speculations to the uses of life in the solution of problems.

7. Elementary geometry is that which is employed in the consideration of right lines and plane surfaces, with the solids generated from them.

8. Geometry depends wholly on definitions and axioms.

9. The definitions in geometry are clear, plain, and universal, such as

"A point has neither parts nor magnitude."

"A line is length without breadth or thickness."

"A surface has length and breadth only."

"A solid is any thing that has length, breadth, and thickness."

"An angle is an opening or inclination of two lines meeting in a point."

"If one line standing on another, makes the angles on both sides equal, those angles are right angles, and the line standing on the other is a perpendicular to that on which it stands."

"A triangle is a plain figure, bounded by three lines or sides."

"A circle is a plain figure bounded by a curve line, called the circumference, every part of which is equally distant from a point within, called the centre," &c. &c.

10. An axiom is a manifest truth not requiring any demonstration: as the following

Examples.—"Things equal to the same thing are equal to one another." "The whole is greater than any of its parts, and equal to all its parts." "Magnitudes which coincide with one another, or which exactly fill the same space, are equal to one another." "If equal things are taken from equal things, the remainders are equal." &c.

QUESTIONS FOR EXAMINATION.

1. What is geometry?
2. From whence was the term derived?
3. What was the occasion of the invention of geometry?
4. How is geometry distinguished?
5. What is meant by theoretical geometry?
6. What is the practical geometry?
7. What is meant by elementary geometry?
8. On what does geometry depend?
9. How are the definitions in geometry characterized?
How is a point defined?
What is the definition of a line?
What is a surface?
What is a solid?
What is a triangle?
How is a circle defined?
10. What is an axiom?
Give the examples of axioms.

LESSON THE SECOND.

1. Postulates are things required to be granted as true, or possible, before we proceed to demonstrate a proposition.

Examples.—"Let it be granted that a straight line may be drawn from any one point to any other point." "Or that a straight line may be produced to any length." "Or that a circle may be described from any centre."

2. A proposition is when something is proposed either to be done, or to be demonstrated, and is either a problem or a theorem.

3. A problem is something proposed to be done.

Example 1. To divide a given line A B fig. 3. into two equal parts.

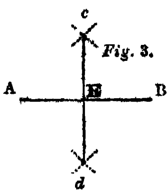


Fig. 3.

From the points A and B as centres, and with any opening of the compasses greater than half A B, describe arcs cutting each other in c and d, and draw the line $c\ d$, and the point E where the line $c\ d$; cuts AB is the middle point required.

Ex. 2.—To raise a perpendicular to a given line, C D, at A.

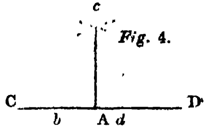


Fig. 4.

Take any two equal distances A b, A d, and from the points b and d with any opening of the compasses greater than b A, describe the arcs cutting each other in c, and draw the line A c, which is perpendicular to C D.

Example 3.—To bisect the angle B, or to divide it into two equal angles. Fig. 5.

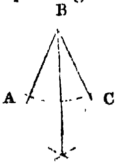
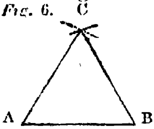


Fig. 5.

From the point B, with any radius, describe the arc A C, and from the points A and C, with the same radius, describe the arcs cutting one another at b, and draw b B, which will bisect the angle A B C.

Example 4.—To describe an equilateral triangle, A B C, that is a triangle whose three sides are equal to a given line. Fig. 6.

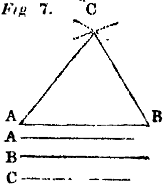
Fig. 6.



Let A B be the given line: from the points A and B, with an opening of the compasses equal to A B, describe the arcs cutting each other in C, and from the point of intersection draw A C, and C B, and the thing is done.

Example 5.—To describe a triangle whose sides shall be equal to three given lines, fig. 7. Let the lines be A B C.

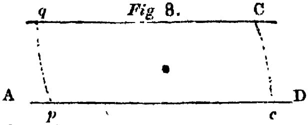
Fig 7.



Take B as the base A B, then from A, with an opening of the compassses equal to C, and from B with an opening of the compasses equal to A, describe the arcs cutting one another in C; draw the lines C A and C B, and the thing is done.

Example 6.—Through a given point C to draw a line parallel to a given line, A D. Fig. 8.

Fig 8.



Take any point p, in A D: upon p and C, with the distance p C, describe two arcs C c and p q, cutting the line A D in p and c.—Make p q equal to C c, and through the points q and C draw a line which will be parallel to A D.

Ex. 7.—To describe a square on a given line, A B. Fig. 9.

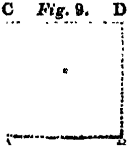
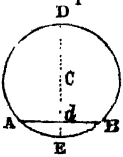


Fig. 9.

Raise a perpendicular at each end of the line A B equal to its length, and draw C D, and the thing is done.

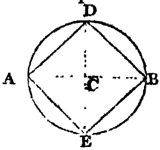
Example 8.—To find the centre C of any circle. Fig. 10.



Draw a chord, A B, at pleasure, bisect it in *d*, with the diameter D E, which diameter being bisected give C as the centre.

Fig. 10.

Example 9.—To inscribe a square in a given circle. Fig. 11.



Draw the diameter A B, and through C draw D E perpendicular to A B, and join A D, D B, B E, and E A, which will form a square.

Fig 11.

Example 10.—In a given circle to describe a regular polygon. Divide the circumference of the circle into as many equal parts as there are sides in the polygon, and join the points of division.

4. A theorem is something proposed to be demonstrated.

5. A corollary is a consequent truth, deduced from some preceding truth or demonstration.

[We shall give an example or two of theorems.]

It is found by mathematical demonstration,

(1.) That one line standing upon another makes with it two angles, equal to two right angles.

(2.) That if one side of a triangle be produced, the external angle will be equal to both the internal and opposite angles.

(3.) That the three angles in every plane triangle are equal to two right angles.

These, with the method of bisecting an angle [See p. 171] may be considered as introductory to the famous theorem, commonly known as the "pons assinorum," or asses' bridge, so denominated from its difficulty in the common Elements of Euclid: this is,

(4.) The angles at the base of an isosceles triangle, A B C, (that is, of a triangle whose two legs A B and B C are equal) are equal to each other. Fig. 12.

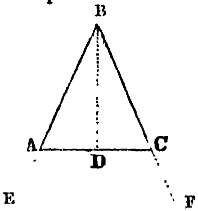


Fig. 12.

Demonstration.—Bisect the angle A B C by the line B D, then the triangle A B D and B D C having the side A B = B C, B D common and the angle A B D = C B D, will also have the angle A equal to the angle C. For if the triangle B C D were to turn on B D as on a hinge, it would be found that it exactly coincided with the triangle A B D in all its parts.

The corollaries to this theorem are: (1.) That the line which bisects the vertical angle of an isosceles triangle, bisects the base, and is perpendicular to it. (2.) That every equilateral triangle is likewise equiangular. (3.) If the sides of an isosceles triangle be produced to E and F, the angles under the base are equal, that is, E A D = F C D: because the line D A falling upon B E makes two angles,

B A D + E A D = two right angles.

B C D + F C D = two right angles for the same reason.

Taking away therefore B A D = B C D, and the remainders E A D and F C D are equal.

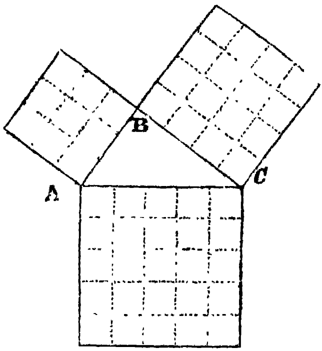


Fig. 13.

(5.) In any right angled triangle, A B C, the squares upon the sides A B and B C, fig. 13, taken together, are equal to the square on the hypothenuse A C. This is called the Pythagorean theorem, because Pythagoras is said to have offered to the gods 100 oxen as a sacrifice, in gratitude for the discovery.

The geometrical proof of this theorem is too difficult for a work of this kind, we shall therefore substitute an arithmetical solution: suppose the side AC = 5, BC = 4, AB = 3,

then $5^2 = 4^2 + 3^2$, or $25 = 16 + 9$, and so it is shewn in the adjoining figure.

Corollary. Hence the square upon either of the sides A B, or B C, including the right angle, is equal to the difference of the squares of the hypothenuse and the other side: or equal to a rectangle, contained under the sum and difference of the hypothenuse and the other side: thus

$$4^2 = 5^2 - 3^2 \text{ or } 16 = 25 - 9$$

$$4^2 = \overline{5 \times 3} \times \overline{5 - 3} = 8 \times 2 = 16.$$

6. Upon geometry depend the sciences of trigonometry, mensuration, &c.

QUESTIONS FOR EXAMINATION.

1. What are postulates?

Give the examples.

2. What is a proposition?

3. What is a problem?

How do you divide a given line into two equal parts?

How do you erect a perpendicular on a given line.

In what manner do you bisect a given angle?

How do you describe an equilateral triangle?

How do you describe a triangle whose sides shall be equal to three given lines?

How do you draw a line parallel to a given line?

How do you describe a square on a given right line?

How do you find the centre of a circle?

How do you inscribe a square in a circle?

How do you inscribe a regular polygon in a circle?

4. What is a theorem?

5. What is a corollary?

What is proved respecting one line standing upon another?

What is the external angle, made by producing one side, equal to?

What are the three angles in a triangle equal to?

What does the pons-assinorum prove?

How is it demonstrated?

What are the corollaries deduced from it?

What is the Pythagorean theorem?

Give the arithmetical proof.

What is the corollary deduced from it?

6. What sciences depend on geometry?

ON THE

MATHEMATICAL ARTS AND SCIENCES.

TRIGONOMETRY, MENSURATION, CONIC SECTIONS.

"It must be remembered that mathematical science, learning, art, or whatever we choose to call it, is wholly of human creation or invention, as much as a rule, compass, quadrant, or any philosophical instrument, apparatus, or method whatever. It has no prototype in nature: it is merely a philosophical contrivance for the purpose of better understanding and interpreting nature, or of becoming more accurately and intimately acquainted with her."—*London Encyclopædia.*

TRIGONOMETRY, or the art or science of measuring angles or sides of triangles, or the solution of triangles, is founded on the mutual proportions which subsist between the sides and angles of triangles; which proportions are known by finding the relations between the radius of a circle, and certain other lines drawn in and about the circle, called chords, sines, tangents, and secants. The manner they are continued the pupil will understand, if he consults the figure 14. The proportion of the sines, tangents, &c. to their radius, is sometimes expressed in common numbers, and then called natural sines, tangents, and secants; sometimes in logarithms, and then called *artificial sines,* &c.; and sometimes actually laid down upon a scale, by which and a pair of compasses any problem in trigonometry can be wrought; though not by any means so correct, as by logarithms, which are arranged on tables for use, and which plan I recommend above all others to the student as most correct: and with this brief notice of Trigonometry I will at once refer him to the lessons.

Of MENSURATION, a much more extended description must be given, and first:—the term in general denotes the act or art of measuring lines, superfices, and solids; and it is, next to arithmetic, a subject of the greatest use and importance, both in affairs that are absolutely necessary in human life, and in every branch of mathematics; a subject by which sciences are established, and commerce is conducted; by whose aid we manage our business, and inform ourselves of the wonderful operations in nature; by which we measure the heavens and the earth, estimate the capacities of all vessels and the bulk of all bodies, guage our liquours, build edifices, measure our lands and the works of artificers, buy and sell an infinite variety of things necessary in life, and are sup-

plied with the means of making the calculations which are necessary for the construction of all machines.

It is evident that the close connection of this subject with the affairs of men would very early evince its importance to them; and accordingly the greatest among them have paid the utmost attention to it; and the chief and most essential discoveries in geometry in all ages have been made in consequence of their efforts in this subject. Socrates thought that the prime use of geometry was to measure the ground, and, indeed, as we have in the preceding lessons seen, this business gave name to the subject; and most of the ancients seem to have had no other end besides mensuration in view in all their geometrical disquisitions. Euclid's Elements are almost entirely devoted to it; and although there are contained in them many properties of geometrical figures which may be applied to other purposes, and, indeed, of which the moderns have made the most material uses in various disquisitions of exceedingly different kinds, notwithstanding this, Euclid himself seems to have adapted them entirely to this purpose; for, if it is considered that his Elements contain a continued chain of reasoning and of truths, of which the former are successively applied to the discovery of the latter: one proposition depending on another, and the succeeding propositions still approximating towards some particular object, near the end of each book. And when at last we find that object to be the quality, proportion, or relation, between the magnitudes of figures both plane and solid, it is scarcely possible to avoid allowing this to have been Euclid's grand object. Accordingly he determined the chief properties in the mensuration of rectilineal plane and solid figures; and squared all such planes, and cubed all such solids. The only curve figures which he attempted besides, are the circle and sphere; and when he could not accurately determine their measures, he gave an excellent method of approximating to them, by showing how in a circle to inscribe a regular polygon which should not touch another circle, concentric with the former, although their circumferences should be ever so near together. But although he could not square the circle, nor cube the sphere, he determined the proportion of one circle to another, and of one sphere to another, as well as the proportions of all rectilineal and similar figures to one another.

Archimedes took up mensuration where Euclid left it. He was the first who squared a curvilineal space. In his time the conic sections were admitted in geometry, and he

applied himself closely to the measuring of them, as well as other figures. Accordingly he determined the relations of spheres, spheriods, and coniods, to cylinders and cones; and the relations of parabolas to rectilineal planes, whose quadratures had long before been determined by Euclid. He has left us also his attempts upon the circle; he proved that a circle is equal to a right-angled triangle, whose base is equal to the circumference, and its altitude equal to the radius; and consequently that its area is found by drawing the radius into half the circumference; and so reduced the quadrature of the circle to the determination of the ratio of the diameter to the circumference; but which, however, has not yet been found.

Throughout the whole of the works of this great man, which are chiefly on mensuration, he every where discovers the deepest design, and displays the finest invention; and seems to have been, with Euclid, exceedingly careful of admitting into his demonstrations nothing but principles perfectly geometrical and unexceptionable; and although his most general method of demonstrating the relations of curved figures to straight ones, is by inscribing polygons in them, yet to determine those relations, he does not increase the number and diminish the magnitude of the sides *ad-infinitum*: but for this plain fundamental principle, allowed in Euclid's Elements, viz. that any quantity may be so often multiplied, or added to itself, as that the result shall exceed any proposed finite quantity of the same kind, he proves that to deny his figures to have the proposed relations, would involve an absurdity.

Several other eminent men among the ancients wrote upon this subject, both before and after Euclid and Archimedes. Among these are to be reckoned Hippocrates, Plato, Apollonius, Philo, and Ptolemy; most of whom wrote of the quadrature of the circle: and those after Archimedes by his method, usually extended the approximation to a greater degree of accuracy. Many of the moderns have also prosecuted the same problem of the quadrature of the circle, after the same methods, to greater lengths.

Hence it appears, that all or most of the material improvements or inventions in the principles or methods of treating of geometry, have been made especially for the improvement of this chief part of it—mensuration; which abundantly shews the dignity of the subject: a subject which, as Dr. Barrow says, after mentioning some other things, "deserves to be more curiously weighed, because from hence a

name is imposed upon that mother and mistress of the rest of the mathematical sciences, which is employed about magnitudes, and which is wont to be called GEOMETRY, (a word taken from antient use, because it was first applied only to measuring the earth, and fixing the limits of possessions) though the name seemed very ridiculous to Plato, who substitutes in its place the more extensive name of METRICS, or MENSURATION; and others after him give it the title of pantometry, because it teaches the method of measuring all kinds of magnitudes."

CONIC SECTIONS, are the figures formed by cutting a cone by a plane: and, as the student will perceive by the lessons, they are five in number, corresponding to the different positions of the cutting plane, and that the last three are particularly and peculiarly called conic sections. The more ancient geometricians admitted only the right cone into their geometry, and they supposed a section made of it by a plane perpendicular to one of its sides; and as the vertical angle of a right cone may be either right, acute, or obtuse, this method of cutting these several cones produced all the three conic sections.

There have been two methods employed in treating of the conic sections; by the one they are considered as cut out of the solid cone, which is the method of the ancients, and some of the most elegant writers of the moderns; and by the other method certain curves are defined, either from some property by which any number of points may be found in them, or else by which they may be described mechanically upon a plane; or they are defined by means of an algebraical equation; and in either case these curves are shewn to have the very same properties as those which are formed by the intersections of a plane and cone. Each of these methods has its advantages; although some of the demonstration writers who have treated the subject geometrically by the latter be short and perspicuous, yet there are others upon which depend some of the principal properties, that are tedious and difficult. The demonstrations of writers who have pursued the first method, are free from this objection, being generally plain and concise; but they have been obliged to introduce so many previous propositions concerning the properties of lines touching and cutting conical surfaces, in order to arrive at the principal properties of the three sections, that it requires a considerable portion of time and resolution for a beginner in mathematical studies to go through them.

The conic sections are of great use in physical and geometrical astronomy, as well as in the physico-mathematical sciences, and therefore they have been much cultivated ever since their great importance in these sciences has been known. The Abbé Boscovich has deduced the properties of the conic sections in a very elegant manner, from a property common to them all: and the same method has also been followed by the Rev. T. Newton, of Jesus College, Cambridge, in a very neat treatise upon the subject.

TRIGONOMETRY.

LESSON THE FIRST.

1. Trigonometry is the science which teaches how to measure the sides and angles of triangles; it is either plane or spherical.

2. Plane trigonometry treats of the analogies of plane triangles, and of the methods of determining their sides and angles.

Illustration.—For the purpose of trigonometry it is not only requisite that the peripheries of circles, but also that certain right lines in and about a circle, should be divided into some assigned number of equal parts. These lines are denominated sines, tangents, secants, &c.

3. The sides of plane triangles may be estimated by inches, feet, yards, &c. or by abstract numbers; but the angles are measured by the arcs of a circle contained by the two legs, having the angular point for its centre.

4. Every circle is supposed to be divided into 360 equal parts called degrees; each degree into 60 equal parts, called minutes; and each minute into 60 equal parts, called seconds. Degrees, minutes, and seconds are marked at the tops of the figures by which the arc is denoted, thus $12^\circ\ 2'\ 22''$ means twelve degrees, two minutes, and twenty-two seconds.

5. An angle is said to be of as many degrees, minutes, seconds, &c. as are contained in the arc or part of the circumference by which it is measured.

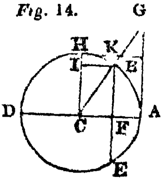
6. A right angle is measured by the fourth part of

the circumference or 90°: an obtuse angle is greater than a right angle; and an acute angle is less than a right angle.

7. The difference of an arc from 90° is called its *complement;* that is, in an arc or angle of 35°, the complement is 55°. A B, in figure 14, is the complement of H B.

8. The difference of an angle from 180° is called its *supplement:* thus A B is the supplement of B D, the one being 55° and the other 125°.

Fig. 14.



9. A *chord* or *subtense* of an arc is a right line drawn from one extremity of an arc to the other: thus B E is the chord or subtense of the arc B A E or B D E.

10. The *sine,* or *right sine,* of an arc is a right line drawn from one extremity of the arc perpendicular to the diameter passing through the other extremity: B F is the sine of the arc A B or B D.

11. The *versed sine* of an arc is the part of the diameter intercepted between the arc and its sine: A F is the versed sine of A B, and D F of the arc D B.

12. The *co-sine* of an arc is the part of the diameter intercepted between the centre and the sine, and is equal to the sine of the complement of that arc; thus C F is the co-sine of the arc A B, and is equal to B I, which is the sine of its complement.

13. The *tangent* of an arc is a right line touching the circle in one extremity of that arc, and continued from thence to meet a line drawn from the centre through the other extremity, which line is called the *secant* of the same arc: thus A G is the tangent, and C G the secant of the arc A B.

14. The *co-tangent* and *co-secant* of an arc, are the tangent and secant of the complement of that arc; thus H K and C K are the co-tangent and co-secant of the arc A B.

15. The lines above described belong equally to an angle as to the arc by which it is measured: and all of them, except the chords and versed sines, are common to two arcs and angles, which are the supplements of each other.

Example.—If the sine, tangent, &c. of an arc above 90° are required, it is the same thing to find the sine, tangent, &c. of its supplement, or what it wants of 180°: that is, the sine, tangent, &c. of 105° is the same as the sine, tangent, &c. of 75°.

16. These lines are called the natural sines, tangents, &c. of the arcs or angles to which they belong: and the logarithms of the numbers by which they are represented, are the logarithmic sines, tangents, &c.

17. Tables are calculated to a given radius, &c. every degree, minute &c. of the quadrant or 90°. The natural sines, tangents, &c. are calculated to a radius of 1; but the logarithmic sines, tangents, &c. are calculated to a radius of 10,000,000,000, or 1 with ten ciphers, so that the latter are the logarithms of the former, with ten added to the index.

QUESTIONS FOR EXAMINATION.

1. What does trigonometry teach?
2. Of what does plane trigonometry treat?
Give the illustration.
3. How are the sides and angles of plane triangles estimated?
4. How is every circle supposed to be divided, and how are the degrees, &c. marked?
5. How is an angle measured?
6. What are right, obtuse, and acute angles?
7. What is meant by the complement of an arc or angle?
8. What is meant by the supplement of an arc or angle?
9. What is the chord or subtense of an arc or angle?

[This and the following questions should be answered by references to the figure.]

10. What is the sine of an arc or angle?
11. What is the versed sine of an arc?
12. What is the co-sine of an arc?
13. What is the tangent of an arc, and what the secant?
14. What are co-tangents and co-secants?

15. To what do these lines belong, and which of them are common to two arcs?

Give the example.

16. What are these lines called?

17. How are tables calculated?

LESSON THE SECOND.

1. In every plane triangle three things must be given to find the rest, and of these three, one at least must be a side.

2. In every right-angled triangle, if the hypothenuse or longest side be made the radius of the circle, the other two sides, or legs, will be sines of the opposite angles; but if either of the legs, including the right angle, be made radius, the other leg becomes the tangent of its opposite angle, and the hypothenuse the secant of the same angle.

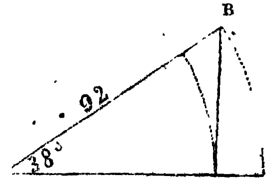


Fig. 15.

If in the triangle A B C the hypothenuse A B is made the radius, B C will be the sine of the angle A, and A C the sine of the angle B. But if A C be made radius, then B C becomes the tangent of the angle A, and A B the secant.

3. All the cases of plane trigonometry may be resolved either by geometrical construction, by arithmetical computation, or instrumentally.

Example.—*By geometrical construction.* Lay down the known side or sides by a scale of equal parts, and the angle by means of a protractor, and then measure the unknown parts by the same scale or instrument from which the others were taken.

4. In a right-angled triangle two sides must always be given, or all three angles and one side, to find the rest.

Example.—*By calculation.* To find B C we should say as
Radius : 92 : : Sine of 38° : B C.

If the side A C were required, then since the angle A is 38°, the angle B must be 52°, because the angle C being a right angle, the other two taken together must be equal to a right angle, or 90°, and we should say as

Radius : 92 : : Sine of 52° : A C.

5. The sides of any plane triangle are to each other as the sines of their opposite angles.

Example (1.)—To find an angle: We say, "as any side is to the sine of its opposite angle, so is any other side to the sine of its opposite angle."

(2.) To find a side: we say, "As the sine of any angle is to its opposite side, so is the sine of any other angle to its opposite side."

[There are other cases according to the parts given, but as these involve more difficulties they are passed over; we shall conclude with referring to a few other properties of triangles, in addition to those already noticed.]

6. The perpendiculars bisecting the three sides of a triangle, all intersect in one point, and that point is the centre of the circumscribing circle.

Corollary.—Hence a circle may be drawn through any three points not in a straight line.

7. Three lines bisecting the three angles of a triangle, all intersect in one point, and that point is the centre of the inscribed circle.

8. The area of any triangle is found by multiplying the base by the altitude, and taking half the product.

9. In a right-angled triangle, if a perpendicular be let fall from the right angle upon the hypothenuse, it will divide it into two other triangles similar to one another, and to the whole triangle.

QUESTIONS FOR EXAMINATION.

1. What things are necessary to be known in triangles to find the rest?

2. If in a right-angled triangle the hypothenuse is made radius, what are the legs?

Explain this by the example.

3. How can the cases in plane trigonometry be resolved?

4. What are required to be given in the solution of right-angled triangles?

Give the example.

5. What is the general rule respecting the sides of any plane triangle?

Give the examples.

6. What will be the resulting consequence of three perpendiculars bisecting the sides of a triangle?

What is the corollary deduced from it?

7. What will be the resulting consequence of three lines bisecting the three angles of a triangle?

8. How is the area of a triangle found?

9. What happens when a perpendicular is let fall from a right angle to the hypothenuse of a right angled-triangle?

MENSURATION.

LESSON THE FIRST.

1. MENSURATION is the art of ascertaining the contents of superficial areas, or planes, and of solids: it is also applied to determine the lengths, heights, depths, or distances of bodies and objects.

2. Accessible lines are measured by applying to them some certain measure, as an inch, a foot, a chain, &c. a number of times.

3. Inaccessible lines must be measured by angles which are taken with a quadrant divided into degrees, minutes, and seconds.

4. The measure of a plane figure is called its area, which determines the extension of bodies as to length and breadth.

5. The area of a figure is the measure of its surface without any regard to its thickness.

6. The surfaces of bodies are measured by squares, as square inches, square feet, square yards, &c. that is, by squares whose sides are inches, feet, yards, &c. according to the following:

TABLE.

144	square inches	make	1		square foot.	
9	..	feet	..	1	..	yard.
$30\frac{1}{4}$	..	yards	..	1	..	pole.
16	..	poles	..	1	..	chain.
40	..	poles	..	1	..	rood.
10	..	chains,	or	4	..	roods, 1 square acre.
640	..	acres	..	1	..	mile.
4840	..	yards	..	1	..	acre.

7. The area of a parallelogram, whether it be a square, rectangle, rhombus, &c. is found by multiplying the length by the perpendicular height.

Example 1.—For how many yards of painting shall I have to pay for a room, of which the two sides are 20 feet by 12, and the two ends 16 by 12.

$$\begin{array}{r} 20 \times 12 = 240 \\ 16 \times 12 = 192 \\ \hline 432. \end{array}$$

Therefore $432 \times 2 = 864$ number of feet in the sides and ends of the room, which divided by 9 gives the number of yards, or $\frac{864}{9} = 96$ yards.

Example 2.—How many square feet are there in a table 12 feet long, and $5\frac{1}{2}$ broad. Ans. $12 \times 5\frac{1}{2} = 66$ feet.

Example 3.—How many acres are there in a field that measures 14 chains in length, by $12\frac{1}{2}$ in breadth. $14 \times 12\frac{1}{2} = 175$, which divided by 10 gives $17\frac{1}{2}$ acres for the answer.

8. The area of a triangle is found by multiplying one of its sides by the perpendicular let fall upon it from its opposite angle, and dividing the product by 2.

Example.—How many square feet are there in a triangular hip of the roof of a house, whose base is 20 feet, and perpendicular 15 feet. Ans. $\frac{20 \times 15}{2} = 150$ feet.

9. All right line figures may be measured in the same manner, because they may all be divided by lines into parallelograms or triangles.

10. A four-sided figure will be divided into two triangles by one line connecting the opposite angles; a five-sided figure by two lines, making three triangles;

a six-sided figure will require three diagonals, which will make four triangles, and so on.

11. The circumference of a circle is found by multiplying the diameter by 3,1416.

Example.—If the diameter be 7, the circumference is $3.1416 \times 7 = 21.9912$, or 22 nearly.

Corollary.—Hence the diameter of a circle is to the circumference as 7 to 22, which is sufficiently accurate for all common purposes.

12. The area of a circle is found by multiplying the square of the diameter by .7854, and the product will be the area.

Example.—What is the area of a circle whose diameter is 50 yards. Ans. $.7854 + 50^2 = .7854 \times 2500 = 1963\frac{1}{2}$ yards.

QUESTIONS FOR EXAMINATION.

1. What is mensuration, and to what is it applied?
2. How are accessible lines measured?
3. How are inaccessible lines measured?
4. What is the area of a figure, and what does it determine?
5. What is the area of a figure?
6. How are surfaces of bodies measured?
Repeat the table.
7. How do you find the area of a parallelogram?
Work the examples.
8. How is the area of a triangle found?
Give the example.
9. In what way are other right lined figures measured?
10. Into how many triangles can a four-sided, five-sided figure, &c. be divided?
11. How is the circumference of a circle found?
Give the example.
What corollary is deduced from this?
12. How is the area of a circle found?
Give the example.

LESSON THE SECOND.

1. A solid is a figure that has length, breadth, and thickness, and its measure is called the solidity, capacity, or contents.

2. Solids are measured by cubes, whose sides are yards, feet, inches, &c, and the solidity, capacity, or contents of a body is said to be so many cubical inches, feet, &c.

TABLE.

1728	cubical	inches make	1	cubical	foot.
27	..	feet ..	1	..	yard.
$166\frac{3}{8}$	..	yards ..	1	..	pole.
64000	..	poles ..	1	..	furlong.
512	..	furlongs ..	1	..	mile.

3. A prism is a solid whose ends are any plane figures which are equal and similar, and its sides are parallelograms.

4. A cube is a square prism having six sides, which are all equal and squares.

5. The solidity or content of a cube is found by multiplying the area of the base by the height.

Example 1.—How many cubical feet are there in a block of stone whose sides are 45 inches long: and what does it weigh, supposing there are 16 feet in a ton?

$45 \times 45 = 2025 =$ area of the base.

$2025 \times 45 = 91125 =$ cubical inches, and

$\frac{91125}{1728} = 52.73$ cubical feet, or nearly $52\frac{3}{4}$ cubical feet.

And its weight $\frac{52.73}{16} = 3\frac{1}{4}$ tons.

Example 2.—What is the contents of a leaden water cistern, in cubical inches, and also in gallons, which is 3 feet long, 2 feet wide, and $2\frac{1}{2}$ deep?

$3 \times 2 = 6$ feet $=$ area of the base.

$6 \times 2\frac{1}{2} = 15$ feet $=$ cubical contents in feet.

$15 \times 1728 = 25920 =$ cubical inches.

And since 282 cubical inches $= 1$ gallon,

therefore $\frac{25920}{282} = 92$ gallons nearly.

6. A cylinder is a round prism, which has two equal circles for its ends: and to find its contents we multiply the diameter of its end by 3.1416, which gives its circumference, and this by .7854, which gives the area of the base, and this product by its height gives the solid contents.

Example.—What is the contents of a cylinder 15 feet high, and the diameter of the base 3 feet?

Answer $3 \times 3.1416 = 9.4248$
$9.4248 \times .7854 = 7.4$
$7.4 \times 15 = 111$ cubical feet.

7. A pyramid is a solid whose sides are triangles meeting in a point at the top, and the base is any plane figure.

8. To find the contents, "Multiply the base by the perpendicular height, and take one-third of the product."

Example.—What are the solid contents of a square pyramid whose height is 30, and each side of its base 3 feet?

$3 \times 3 = 9 =$ area of base.
$9 \times 30 \div 3 = 9 \times 10 = 90$ feet.

9. A sphere is a solid bounded by one continued convex surface, every point of which is equally distant from a point within, called the centre.

10. To find the solid contents of a sphere, "Multiply the surface by one-third of the radius, and the product will be the solidity;" or "Multiply the cube of the diameter by .5236 for the solidity."

Example.—What are the solid contents of the earth, supposing its diameter to be 8000 miles in length?

$8000 \times 8000 \times 8000 = 512{,}000{,}000{,}000$ and
$512{,}000{,}000{,}000 \times .5236 = 268{,}083{,}200{,}000$ miles.

11. The circumference of an ellipse is found by multiplying the sum of the two axes by $\frac{3.1416}{2}$ or by 1.5708.

Example.—The circumference of an ellipse whose diameters are 9 and 7, is equal $\overline{9 + 7} \times 1.5708 =$
$16 \times 1.5708 = 25.1328$ answer.

12. The area of an ellipse is found by multiplying the product of the two axes by .7854.

Example.—Suppose the axes of the ellipse to be 9 and 7: then $9 \times 7 \times .7854 = 63 \times .7854 = 49.48$ answer.

13. The length of any arc of a circle is equal to eight times the chord of half the arc, minus the chord of the whole arc, and the remainder divided by 3.

Supposing the chord of the whole arc to be A and that of half the arc to be a, then the arc itself will be $\frac{8a - A}{3}$.

14. The concave or convex surface of an arched ceiling is equal to the length of the arch, multiplied by the length of the ceiling.

Example.—To find the concave surface of a circular ceiling 26 feet long, and whose arch is represented by figure 16.

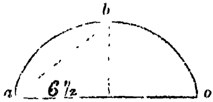


Fig. 16. 13

Here the chord of the whole arc is 13 feet, and the perpendicular is 3 feet; then the chord of one-half the arc $a\,b$ is equal to $\sqrt{6\frac{1}{2}^2 \times 3^2} = \sqrt{51\frac{1}{4}} = 7.16$ nearly. Therefore by the rule given above, (13) the whole $a\,b\,c$ is equal to $\frac{8 \times 7.16 - 13}{3}$ $= 15$ feet nearly: of course the surface is $15 \times 26 = 390$ feet, or $\frac{390}{9} = 43.33$ yards.

QUESTIONS FOR EXAMINATION.

1. What is a solid, and what is its measure called?
2. How are solids measured?
Repeat the table.
3. What is a prism?
4. How is a cube defined?
5. How do you find the contents of a cube?
Work the examples.
6. What is a cylinder, and how is it measured?
Work the example.
7. What is a pyramid?
8. How are the contents of a pyramid found?
Work the example.
9. What is a sphere?
10. How are the contents of a sphere found?
Work the example.
11. How is the circumference of an ellipse found?
Work the example.
12. How is the area of an ellipse found?
Work the example.
13. How is the length of an arc of a circle found?
14. How is the concave, or convex surface of an arched ceiling found?
Work the example.

CONIC SECTIONS.

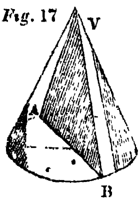
LESSON THE FIRST.

1. Conic Sections are such curve lines as are produced by the mutual intersections of a plane, and the surface of a solid cone.

2. In different positions of the plane there are five different figures or sections, viz. a "triangle," a "circle," an "ellipse," a "parabola," and an "hyperbola."

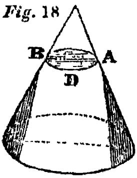
3. The ellipse, parabola, and hyperbola, are peculiarly called conic sections, and the investigation of their nature and properties is the business of "Conics."

Fig. 17



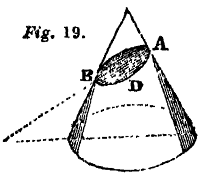
4. If the cutting plane pass through the vertex of the cone, and any part of the base, the section will be a triangle, as V A B.

Fig. 18



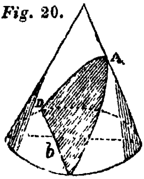
5. If the plane cut the cone parallel to the base, or make no angle with it, the section will be a circle: as A B D. Fig. 18.

Fig. 19.

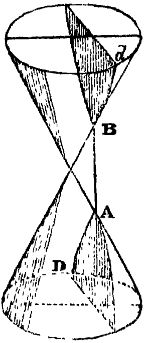


6. The section D A B is an ellipse, and it is formed by cutting the cone obliquely through both sides. Fig. 19.

Fig. 20.



7. When the cone is cut by a plane parallel to one of its sides the section is a parabola, as A D E. Fig. 20.



8. The section is an hyperbola when the cutting plane makes a greater angle with the base than the side of the cone makes: and if the plane be continued, to cut an opposite cone, this latter section is called the opposite hyperbola to the former: thus B *e d* is opposite to A D E. Fig. 21.

9. The vertices of any section are the points where the cutting plane meets the opposite sides of the cone, as A and B. Fig. 21.

Fig. 21.

10. The ellipse and opposite hyperbolas have each two vertices, but the parabola only one.

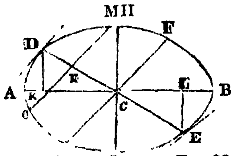


Fig. 22.

11. The axis, or transverse diameter of a conic section is the line A B, fig. 22; B B, fig. 23; and A B, fig. 24.

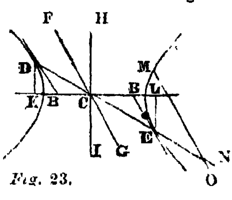


Fig. 23.

The centre C is the middle of the axis: in the ellipse fig. 22, the centre is within the curve: in the hyperbola it is without the curve: but in the parabola the centre is infinitely distant from the vertex, fig. 23.

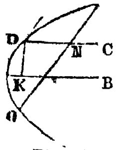


Fig. 24.

13. A diameter is any right line, as A B or D E, drawn through the centre, and terminated on each side by the curve. All the diameters of the parabola are parallel to the axis, and infinite in length, because there is no termination to the line A B, fig. 24.

14. The conjugate to any diameter is the line drawn through the centre, and parallel to the tangent of the curve at the vertex of the diameter: thus H I, fig. 22, would be parallel to tangents drawn through A or B, and G F is parallel to tangents drawn through D and E; therefore H I is conjugate to A B, and G F is conjugate to D E.

QUESTIONS FOR EXAMINATION.

1. What are conic sections?
2. How many different figures arise from the cutting of the cone, and what are they?
3. Which are those that are properly called conic sections, and what is the peculiar business of conics?
4. How is the triangle formed?
5. How is the circle formed?
5. How is the ellipse formed?
7. How is the parabola formed?
8. How is the hyperbola formed?
Explain this and the four preceding articles by the figures.
9. What are the vertices of a section?
10. How many vertices have the different sections?
11. Point out what is the axis of a conic section?
12. What is meant by the centre of a conic section?
13. What is meant by the diameter of a conic section?
14. What is meant by the conjugate to a diameter?

LESSON THE SECOND.

1. An ordinate to a diameter is a line parallel to its conjugate, or to the tangent at its vertex, and terminated by the diameter and curve: thus D K, E L are ordinates to the axis A B; fig. 22, 23, 24: and M N, N O, are the ordinates to D E. Ordinates are perpendicular to their axis.

2. An absciss is a part of any diameter contained between its vertex and an ordinate to it: thus A K, K B, fig. 22, are abscisses to the ordinate D K; and D N, N E are abscisses to the ordinate N M.

3. In the ellipse and hyperbola every ordinate has two abscisses, in the parabola only one.

4. The parameter, or latus rectum of any diameter, is a third proportional to that diameter and its conjugate: that is, if p = parameter, then fig. 22, A B : H I : : H I : p.

5. The focus is the point in the axis where the ordinate is equal to half the parameter; thus D K, and E L are each equal to the semi-parameter.

6. The ellipse and hyperbola have each two foci, but the parabola only one.

7. The conic sections are allied to each other, so that the one may be changed to another, by being increased or diminished.

ILLUSTRATION.—The curvature of the circle is easily made to pass into an ellipse: for a circle is a figure drawn from a single point within, called the centre: but an ellipse is a curved figure drawn from two points within called foci: if therefore, instead of a single point, two points be assumed at ever so short a distance from the centre, and on each side of it, the curve becomes an ellipse. Hence is derived the common method of describing an ellipse.

Take a thread of the length of A B, fig. 22, the transverse axis, and fix its two ends in the foci K and L by two pins; and carry a pen or pencil round by the thread, keeping it always stretched, and its points will trace out the curve line.

QUESTIONS FOR EXAMINATION.

1. What is the ordinate to a diameter?
Explain this by the figures
2. What is meant by an absciss?
3. How many abscisses are there to each ordinate?
4. What is meant by the parameter of a conic section?
5. What is the focus?
6. How many foci are there to the several sections?
7. In what way are the conic sections allied to each other?
Give the illustration.
How is an ellipse described?

ARCHITECTURE.

ITS ORIGIN AND HISTORY.

"Next add our cities of illustrious name,
Their costly labour, and stupendous frame."—*Dryden.*

ARCHITECTURE is the art of building, or a science which teaches how to erect buildings either for habitation or defence. The origin of this noble science may be traced in the Indian's hut, and the Greenlander's cave; they shew the rude beginning from which it has grown to its present perfection and magnificence. It is an art of the first necessity, and almost coeval with the human species. Man from seeking shade and shelter under the trees of the forest, soon felt the necessity and saw the utility of bending them to more commodious forms than those in which he found them disposed by nature. To huts made of trees and branches leaning together at top, and forming a conical figure plastered with mud, succeeded more convenient square-roofed habitations.

This art we are assured is as old as Cain: for Moses tells us that he built a city, though what were the materials, or how the buildings were constructed, we are entirely ignorant. It is commonly said, that the first materials employed in building were twigs of trees, wherewith men constructed huts, such as the wigwams in use among the American Indians. This, however, has been disputed. The natural shelter afforded by hollows in the sides of mountains or rocks, it may be supposed, would much more readily suggest the idea of using stones and earth as materials for building houses. Indeed, considering that tents were not invented before the days of Jabal, Tubal-cain's brother, it is very probable that such temporary houses as the Indian wigwams were not orignally known; otherwise the method of covering poles with the skins of beasts, instead of small twig branches, must very soon have taken place. These temporary houses seem to have come into use only when men began to lead an idle wandering life, like the Tartars, and could not be at the trouble of constructing durable habitations in every place, where they were obliged to wander with their cattle; and

Jabal, perhaps, thus took the hint of making portable houses or tents. Accordingly we see, that no nation, except those who are in a perpetually unsettled state, make use of such wretched materials. Even in America, where the human race has appeared in the rudest form, they were no sooner collected into great bodies under the emperors of Mexico and Peru, than stone buildings began to be erected. We are not therefore to look for the origin of architecture in any single nation, but in every nation, when the inhabitants began to leave off their savage way of life, and to become civilized. The origin of regular building hath been deduced from the construction of the meanest huts, in a very natural plausible manner, by several authors.

VITRUVIUS,* the learned and celebrated Roman architect, writes as follows: "Anciently men lived in woods, and inhabited caves; but in time, taking example perhaps from birds, who with great industry built their nests, they made themselves huts. At first they made these huts, very probably of a conic figure, because that is a figure of the simplest structure; and, like the birds whom they imitated, composed them of branches of trees, spreading them wide at the bottom, and joining them in a point at the top; covering the whole with reeds, leaves, and clay, to screen them from tempests and rain. But finding the conic figure inconvenient on account of its inclined sides, they changed both the form and construction of their huts, giving them a cubical figure, and building them in the following manner. Having marked out the space to be occupied by the hut, they fixed in the ground several upright trunks of trees to form the sides, filling the intervals between them with branches closely interwoven and covered with clay. The sides being thus completed, four large beams were placed on the upright trunks; which being well joined at the angles, kept the sides firm, and likewise served to support the covering or roof of the building, composed of many joists, on which were laid several beds of reeds, leaves, and clay. Insensibly mankind improved in the art of building, and invented methods to make their huts lasting, and handsome, as well as convenient. They took off the bark, and other unevennesses, from the trunks of trees that formed the sides; raised them probably,

* Vitruvius, a famous engineer and architect in the time of Julius and Augustus Cæsar: he wrote ten books of architecture, was patronized by the emperors, and though employed in few works of magnificence, his rules were highly esteemed by the ancients, and are still a standard among the moderns.

above the dirt and humidity, on stones, and covered each of them with a flat stone or slate, to keep off the rain. The spaces between the ends of the joists were closed with clay, wax, or some other substance, and the ends of the joists covered with thin boards cut in the manner of triglyphs. The position of the roof was likewise altered, for being, on account of its flatness, unfit to throw off the rains that fell in great abundance during the winter season, they raised it in the middle, giving it the form of a gable roof, by placing rafters on the joists to support the earth and other materials that composed the covering. *From this simple construction the orders of architecture took their rise*; for when buildings of wood were set aside, and men began to erect solid and stately edifices of stone, they imitated the parts which necessity had introduced into the primitive huts; in so much that the upright trees with the stones at each end of them, were the origin of columns, bases, and capitals; and the beams, joists, rafters, and strata of materials, that formed the covering, gave birth to architraves, friezes, triglyphs, and cornices, with the corona, the mutules, the modillions, and the dentils. The first buildings were in all likelihood, rough and uncouth; as the men of those times had neither experience nor tools: but when by long experience and reasoning upon it, the artists had established certain rules, had invented many instruments, and by great practice had acquired a facility in executing their ideas, they made quick advances towards perfection, and at length discovered certain manners of building which succeeding ages have regarded with the highest veneration."

From the earliest antiquity the Egyptians have been considered as the inventors of arts; and in the time of their prosperity all nations sought and studied their philosophy and their sciences; so that "being learned in the arts of the Egyptians" became proverbial. Among other arts derived from them, architecture is generally enumerated; but this I apprehend must be understood as meaning only that species of original architecture where the strength of the fabric was more regarded than the symmetry. Of this kind are the pyramids and the ruins of the magnificent temple at Thebes.

It is not, therefore, unreasonable to conclude, that from Egypt, where the contemporary nations sought the arts and studied the sciences, the Greeks derived their first ideas of building, but which were so changed and improved by being thus transplanted, that it can scarcely be known from what stock they had their origin. The Greeks, anxious to add

elegance to convenience, disregarded the massive and ponderous architecture of the Egyptians, whose ignorance of the arch made it absolutely necessary for them to have small spaces between their columns, and to burden their edifices with large and strong architraves.

This, therefore, may be considered as the probable track by which architecture rose to elegance, for certainly the structures of Egypt are much more ancient than those of Greece; and as it may be considered the best character of buildings that they provide for the comfort and convenience of man, so it must be allowed that the Greeks first rendered them productive of grace, elegance, regularity, and beauty; for to the fine eye, skilful hand, and sublime genius of that nation, is architecture indebted for its rules of harmony, elegance, design, and taste of ornament, which began to arrive at perfection under the fostering care of Pericles, which period including the reign of Alexander the Great, must be considered as its climax of grace, elegance, and beauty, in Greece.

It is a most indubitable fact, that the mind of man is influenced by modes of government: and it is certain that the Greeks, with their independence, lost also their superior vigour of genius; and what remained was, with the spoils of their cities, carried to Rome. Hence it is, that from this period the Romans are to be considered as the encouragers and patronisers of architecture. From this period also its progress was great and rapid, though little was done that could be remarked for its novelty; but the rules of the Greeks were applied to structures so numerous, and of such wonderful extent, that we doubt which most to admire, the original inventors of these sublime rules, or those who applied them to such stupendous buildings.

Although the Romans borrowed their architecture from the Greeks, they did not imitate them in the structure of their private dwellings in every particular. Their magnificence, however, in their temples and public buildings, is yet to be seen in what remains of them, and which are not only models for all modern architects, but have never been surpassed, nor even equalled to this day. But though the art of architecture continued almost at its highest pitch among the Romans for two centuries, it declined exceedingly as the empire began to fall. Tacitus relates, that after the battle of Actium no men of genius appeared; and after the reign of Alexander Severus, a manner of building altogether confused and irregular was introduced, wherein nothing of the true graces and majesty of the former was preserved.

LESSON THE FIRST.

1. Architecture is the art of building, or erecting edifices, whether for habitation, for worship, for ornament, or defence. It is divided into civil, military, and naval.

2. Civil architecture, called architecture simply, by way of eminence, is the art of constructing edifices for the common uses of life.

3. Military architecture is the art of strengthening and fortifying places to screen them from the attacks of enemies.

4. Naval architecture, or ship-building, is that science which teaches the construction of ships and other floating vessels, with that of ports, docks, &c.

5. Architecture had its origin in the inclemency of the season; it has spread wherever the severities of the climate demand shelter or shade, and may be traced in the Indian's hut, and the Greenlander's cave.

6. The assistance required in erecting the meanest residence, was perhaps the first introduction of civil society.

7. The earliest efforts are supposed to have gone no farther than in bringing together a number of trees or large branches, which (leaning together at the top in the form of a cone) were interwoven with twigs, and plastered with mud to exclude the air.

8. The inconveniences of the round habitation is supposed to have led to the introduction of square buildings, and of supports for the cross beams which were to sustain the roof. The trunks of trees first used as supports, gave the rude ideas of columns; these have at length produced those pillars from which are denominated the orders of architecture.

9. The orders form the principal parts of the decora-

tions of buildings. Every order consists of three divisions, the pedestal, the column, and the entablature. *See* fig. 1.

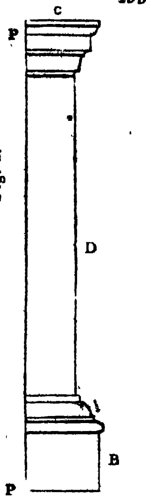
10. The pedestal consists of a base or plinth, the dado or dye, and the cornice. The pedestal is used to elevate the column to a necessary height. See fig. 1.

11. The column includes a base, a shaft, and a capital. See fig. 2—6. p. 201, 202.

12. The entablature consists of an architrave, a frieze, and a cornice, fig. 2.

13. The plinth of a pedestal takes its name from the Greek, of a brick or flat stone on which columns in the early state of architecture are supposed to have stood.

Fig. 1.



B base. C cornice.
D dado. P P pedestal.

14. The dado or dye is so called from its cubical form: and the cornice takes its name from corona, top or summit.

15. The base of a column is its foundation: the shaft is comprehended between the base and capital: and the capital is so denominated from caput the head; the abacus is the upper member of the column, and serves as a covering.

16. The architrave is so called from two Greek words signifying "principal beam," because the architrave is the principal support to the whole entablature.

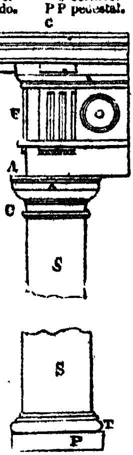


Fig. 2.

A architrave. A abacus. B base.
C capital. C cornice. E entablature
F frieze. P plinth. S shaft.
T torus.

17. The frieze is a large flat face, which the ancients sometimes enriched with the figures of animals, &c. The cornice is the crowning part of the whole.

18. The principal parts of a complete order, except the dado and shaft, are composed of small members which constitute the mouldings.

19. Some of the smaller members are the torus, the astragal, and the scotia. The torus is the swell above the plinth: the astragal is a small round member resembling a ring, which terminates the extremities of the column: the scotia is a hollow moulding used in bases, so called because of the strong shadow which its concavity produces.

QUESTIONS FOR EXAMINATION.

1. What is architecture, and how is it divided?
2. What is civil architecture?
3. To what is military architecture applied?
4. What does naval architecture teach?
5. From what had architecture its origin?
6. What was the first introduction to society?
7. To what did the earliest efforts in architecture extend?
8. What led to square buildings and other improvements in architecture?
9. What do the orders of architecture form, and of what does each order consist?
10. Of what does the pedestal consist?
11. What does the column include?
12. Of what does the entablature consist?
13. From what does the plinth derive its name?
14. Why is the dado or dye so called, and from what does the cornice take its name?
15. Describe the parts of the column.
16. From what does the architrave take its name, and why?
17. What is meant by the frieze?
18. Of what are the principal parts of a complete order composed?
19. Enumerate some of the smaller members and their properties?

LESSON THE SECOND.

1. There are five orders of architecture, viz. the Tuscan, the Doric, the Ionic, the Corinthian, and the Composite, which are distinguished from each other by the column, with its base and capital, and by the entablature. See fig. 1. p. 199.

2. The Tuscan order is characterized by its simplicity and strength; it is composed of few parts, devoid of ornaments, and capable of supporting the heaviest weight. The Trajan column at Rome is of this order, fig. 3.

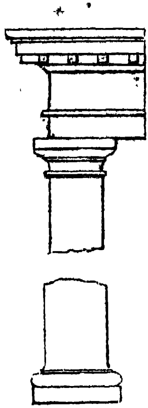


Fig. 3.

3. The Doric possesses nearly the same character for strength as the Tuscan, but enlivened with peculiar ornamants in the frieze and capital, which are inseparable from it. The columns of the temple of Apollo at Delos are of this order. See fig. 2. p. 199.

4. The Ionic order is said to have been first employed in the decorations of the temple of Diana at Ephesus: the volute, scrol, or spiral horn, is a principal ornament of this column. Its ornaments are in a style of composition between the richness of the Corinthian, and the plainness of the Doric orders, fig. 4.

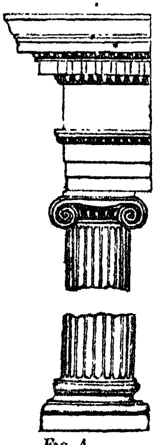


Fig. 4.

5. The Corinthian is the most noble of the five orders, and is known by its capital being adorned with two sorts of leaves, between which rise little

stalks: of these are formed the volutes that support the highest part of the capital, fig. 5.

6. The Composite order is nearly the same as the Corinthian, with the addition of the Ionic volute to the capital, fig. 6.

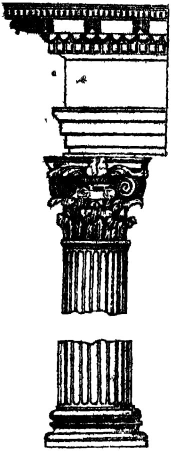


Fig. 5.

7. Each column has its particular base: the Tuscan base is the most simple, having only a torus and plinth: the Doric has an astragal more than the Tuscan. To the Ionic base the torus is larger on a double scotia, with two astragals between. The Corinthian base has two toruses, two scotias, and two astragals. The Composite base has one astragal less than the Corinthian.

8. Pilasters differ from columns only in their plan, which is square, as that of columns is round. Their bases, capitals, and entablatures are the same as those of the columns.

9. Balusters, small columns, or pillars of wood, stone, &c. are used on terraces or tops of buildings for ornament, and to support railing, and when continued they form a balustrade.

10. Corona, a large flat member in a cornice used to screen the underparts of the work, and to prevent the water from running down the column: the under part of the corona is called the soffit.

11. Portico, a continued range of columns covered at top to shelter from the weather: the portico at Palmyra was full four thousand feet long.

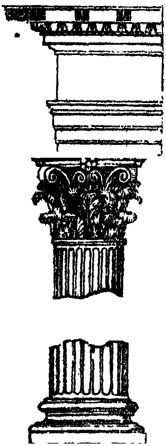


Fig. 6.

12. Gothic architecture originated among the northern nations of Europe, which, after the destruction of the Roman empire, they introduced to the exclusion of the Greek and Roman manner of architecture. It seems peculiarly adapted to religious edifices.

13. The characteristics of Gothic architecture are pointed arches, greater height than breadth in the proportions, and profuse ornament, chiefly derived from an imitation of the leaves and flowers of plants.

14. There are two species of Gothic architecture: the Saxon, which is heavy, plain, robust, like the Tuscan; the other, like the Corinthian architecture, is light and ornamental, and received its finish from the Normans.

15. A grove of tall trees meeting at the top with interweaved branches, is said to be the natural model from which the aisle of the Norman Gothic cathedral is derived.

QUESTIONS FOR EXAMINATION.

1. What are the orders of architecture?
2. How is the Tuscan order characterized?
3. What is the character of the Doric order?
4. Where was the Ionic order first used; what are its principal ornaments, and what is its character?
5. What are the characteristics of the Corinthian order?
6. What is the character of the Composite order?
7. Give an account of the bases of the several columns.
8. In what do pilasters differ from columns?
9. What are balusters?
10. What is the corona, and what is its use?
11. What is a portico, and what length was the portico at Palmyra?
12. From whom did Gothic architecture originate?
13. What are the characteristics of Gothic architecture?
14. What are the species of Gothic architecture?
15. What is said to be the natural model of the Gothic architecture?

NATURAL PHILOSOPHY.

MECHANICS, HYDROSTATICS, HYDRAULICS, PNEUMATICS, ACCOUSTICS, AND OPTICS.

An appreciation and recommendation of Philosophical Knowledge and Scientific Learning.

"The mind that lies fallow but a single day, sprouts up in follies that are only to be killed by a constant and assiduous culture. It was said of Socrates, that he brought philosophy down from heaven, to inhabit among men; and I shall be ambitious to have it said of me, that I have brought philosophy out of closets and libraries, schools and colleges, to dwell in clubs and assemblies, at tea-tables and in coffee-houses."—*Spectator*, Vol. i., No. 10.

"How charming is divine philosophy!
Not harsh and crabbed as dull fools suppose!!"—*Milton.*

MAN is ennobled by understanding and reason. These form the first and chief ground of his distinction and his superiority. These exalt him far above all other creatures of the earth. By these he is related with spiritual beings; by these he takes flight to the regions above, and soars to the seat of God. He is neither altogether material, nor altogether spiritual; not like the beasts of the field, attached to the earth; not incapable, like them, of resisting the impression of external things. He can lift his eyes on high and roam in spirit above terrestrial and visible objects: he can investigate himself; distinguish himself from every thing around him, and separate his thoughts from that which thinks within him; can discriminate the past, the present, and the future, in the conceptions of his capacious mind; has an inward and clear consciousness of his existence and his actions; can inquire into the causes and motives of events, investigate their proportion and affinity to each other, view their connections and consequences; and from what he knows and sees, can judge in a thousand cases of what he knows and sees not yet. How comprehensives is his intellect. How far does his reason venture, and how often does it succeed, in his boldest speculations! Who can compute the multitude, the numberless multitude of ideas, judgments, conclusions, remarks and observations which arise, which associate, and interweave themselves in the human mind, during its short

sojourn on this terrestrial globe, and supply it with matter for everlasting reflection? What is there in the heaven above, or in the earth beneath, in the sea, and in "all deep places," in the visible or the invisible world, in the regions of possibilities and action, in the obscurity of the past, and in the night of the future, what is there that the curiosity of the human mind does not strive to possess, that does not employ its faculties, that it does not endeavour to know, to fathom, to explain, to compare, or to combine with what it already knows?

And who can deny that all things on the earth relate to man; that all are animated, beautified, and connected as the means of human happiness, and for the glory of God? How extensively do the influences and operations of men, either mediately or immediately, prevail! What does he not extort from the very elements, and the recondite powers of nature? And what revolutions and productions does he not bring forth! What desert does not become a paradise by his presence and industry; and what paradise is not more paradisaical when he builds his habitation in it! Let me say to the student, represent to yourself the earth without mankind, without rational creatures on it, and what do you discover it to contain? Certainly still many great beauties; but more savage than gentle, more tremendous than delightful beauties—still, indeed, much life, but life without consciousness, without reflection, without approximate enjoyment, without recollection of the Great Author of it. No, nature is beautiful, enchantingly beautiful; but man adorns it, collects about him the scattered and single beauties, and sees and feels, and enjoys them, and delights in them. Nature is fruitful, inexhaustibly fruitful; but man improves her fertility, guides it, and gives it its most generally useful direction. Nature is full of life; but man diversifies, elevates, and ennobles this life, and is happy in the enjoyment of it. Would we estimate his powerful and benign influence on all things; then we have only to compare the regions inhabited by man with those wherein he has not fixed his abode; to compare the European and Asiatic luxuriance of cities, gardens, fields, with the savage and desolated wilds of America. Here nature languishes for want of cultivation; there plenty and joy meet the traveller with smiles. Here impenetrable forests and vast impassable marshes cover the earth, its undirected and useless fertility stifles and destroys itself, and pestilential vapours obscure its surface; there the sun unimpeded diffuses its light and heat, the waters flow in pleasant streams,

the noisome vapours are dispersed, the winds are admitted to refresh and purify the atmosphere, and the weeds are eradicated from the useful plants. Where man is not, and does not act, there are trackless wastes, there frost, and cheerless silence, and dreadful death prevail; where man appears, where he lives and acts, there he makes him paths, there he decks the earth with flowers and fruits, there the air brings health and strength and pleasant odours with it, there he animates and gladdens all. How much more beautiful, much more glorious is nature now; how rich and beneficent under the guiding hand and the genial attentions and culture of man! All is now the mirror of the Deity, the school of wisdom, the source of pleasure, the means of exercise and perfection, the foretaste of purer joys and higher happiness! How connected now is the visible with the invisible, the present with the future, the terrestrial world with the world of spirits, and the creature with the Creator!

Such then is man; such his faculties and his powers; so extensive are his capacities, so exalted is his vocation, his dignity; so stupendous, beneficent, and extensive are the effects which his understanding, his freedom, his activity, produces. What is his duty, what his interest? To confess and feel his faculties and privileges; to confess and to feel them with a cheerful and grateful heart. To cultivate his understanding, to cultivate his mental faculties with diligence and care. To judge justly of himself, and to treat himself conformably with truth. To feel and acknowledge the value of his reasonable nature, the whole worth of his superior dispositions, capacities, and powers. If he does not do this, he cannot properly or worthily use these dispositions and capacities; neither can he become, nor do, nor enjoy that which he may become, and do, and enjoy by the nature of his appointment.

Every application of our mental faculties that is not totally fruitless, every enlargement of our intellectual horizon, every augmentation of our knowledge and perceptions, every adjustment of our ideas and conceptions, every additional view we get into the immense region of truth, and every ray of light thence falling on our eyes, augments our power, and procures us the purest pleasure, the highest happiness; and how diversified, how inexhaustible is this felicity! Each stone, each mineral, each man, each part of man, the whole material and spiritual world, the visible and invisible, the past, the present, and the future, the possible and the actual, the creature and the Creator; all charm, all employ the curio-

sity, and spirit of observation and enquiry, of the thoughtful student; all guide him forward on the track of truth; all point out to him more or less of it; all shew him arrangement and harmony in the whole and in the parts; all lead him to the prime, eternal Source of being, of life, of power, of perfection; and by these very means procure him satisfaction—the purest, the noblest pleasure. And this pleasure frequently rises to ecstasy, when he has overcome every material impediment that retarded him in his reflections, has obviated some difficulty that bewildered him, solved some knotty point on which he had exercised perspicacity in vain; when he is enabled to fill up any considerable chasm in his knowledge, and see through a series of ideas with greater clearness; to comprehend more fully some part of human science; to find some important and fertile argument or exposition; to make any striking application, any profitable use of his knowledge; or to detect a trace of the truths that insure him a remarkable progress in tilling the field he has chosen to cultivate. How often and how amply must these pleasures requite the naturalist, the astronomer, the geometrician, the philosopher, the chemist, and every other inquisitive mind, for all its exertions and toils in the search after truth! And how little has such an one to fear, lest the sources of these pleasures should ever fail, or the enjoyment of them be turned into disgust! No, here are fountains of pleasure that never fail, which flow through all times and all eternities, and become the more bounteous, the more pellucid and pleasant, the oftener and more copiously we draw from them. And must not philosophy, which procures us this exalted pleasure, be inestimably valuable, and beyond the highest appreciation which can be arrayed of its merits?

How greatly have navigation and commerce been benefitted by astronomical observations! How much have chemical researches contributed to the improvement and perfection of manufactures! How much are architecture, tactics, and every species of mechanical knowledge, indebted to mathematics! What implement is there of the artist, of the artizan, or of the husbandman, that is not more or less improved and perfected by them? How many productions of nature are understood, wrought up, and rendered useful to many important purposes, by the industry of the naturalist! What beneficial institutes in common and civil life, what conveniences in regard of lodging and furniture, of order and safety, of trade and barter, are we not indebted for to philosophical learning, and particularly to geometry and the

sciences related to it! How much is due to the study of law for peace and quiet, and to medicine for life and health, however great the inconveniences of the one may be, and the imperfections of the other! How much agreeable and useful knowledge, how many means of refined social pleasure and noble entertainment have been diffused from all these sources among all classes and conditions of men! I will again ask the ardent student to compare the condition of a country where ignorance and superstition prevail, with the state of another where learning and sciences flourish: how much more barbarism and ferocity, how much more imperfection and confusion, will he find in the one than in the other! How many channels of industry, of art, of pleasure, of domestic and social happiness, are closed to the former, which run and disperse themselves throughout our happy country, bringing life and activity, profit and satisfaction, into all our borders! And I will ask how much more profit and pleasure, of all these various descriptions, may not the whole society promise itself in future from philosophical and scientific learning, since all men are at present far more disposed to render it more generally useful and more serviceable to all ranks and descriptions of persons than ever they were before!

But another most important benefit to be regarded in an appreciation of philosophical knowledge, and one which likewise most powerfully recommends it, is, that it cherishes and extends the light of truth, which superstition and fanaticism, that most baneful brood of darkness, cannot endure, and which it not unfrequently scares and chases back into the obscurity from whence it sprung. It promotes clear thought, nice investigation, sagacious doubt, modest and dispassionate enquiry into the causes, the designs, the connections of things. It arms us against the deceptions of the senses, of the imagination, of the feelings; against the fallacious charms of the extraordinary, the wonderful, the mysterious; against the imposing vigour of a peculiar pensiveness and hidden wisdom, under which ignorance and fanaticism so frequently lurk. Wherever real learning and solid philosophy and science lose their respect and influence, superstition is sure to rise upon their ruins, with all its lamentable and disastrous attendants, ignorance, dastardly fear, and intolerance, spreading terror and thraldom and misery of various kinds throughout the land. Curiosity never totally forsakes the human mind. If a man cannot employ it in regular and rational meditation, he endeavours to satisfy it by conceits and reveries: the invi-

sible, the world of spirits, the future, are always momentous to time. If in his flights into the unknown world he has not for his guide an enlightened and trained reason, but trusts only to obscure sensations, he is then liable to follow every bye-way, every devious track that offers; and who can think upon all the hurtful and ruinous effects of superstition and fanaticism, and not ascribe great praise to science and erudition, which is always counteracting them, and setting bounds to their dominion?

If we wish to see the great doctrines of our holy Christian faith defended against the objections of the infidel and the sneer of the scorner; if we would see their reasonableness evinced, see them purified from all human commixtures; more unfolded and reduced to a connected and consistent whole; delivered in a manner suited to the wants of mankind, and the exigencies of the times; and if we would have them likewise "worthy of all acceptation" to the deep-thinking man, and the mind addicted to doubt; if we would hope to see them in security from all abuse; we must recollect that our hopes and desires will be vain, without the means of various sorts of learned knowledge, they can never be accomplished without the assistance of philosophical perspicacity, without an enlightened and habituated reason. Were it not for learning and solid science, religion would speedily degenerate into superstition and fanaticism. Whereas, the more flourishing and the more general they become, in a country or among a people, so much the greater light is diffused over religion; so much the more is it cherished in its native simplicity and its majestic dignity; and so much the more general must its influence be on human improvement and happiness.

Much, perhaps even the greatest part, of knowledge, and the sciences, as they are termed, will fall away as totally useless in the future life, as the toys and playthings of our childish years; yet must much of the rest still remain, such as are of a nobler kind, of eternal, unchangeable truth, of universal utility; and afford those, who take them with them into that better world, a greater or less advantageous outset, beyond those who are destitute of them. Though, for instance, what the astronomer knows concerning the heavenly bodies, and their relations towards each other, be ever so little in comparison with what in the immense system of the universe is concealed from him, yet at least he understands some few letters in the alphabet of the skies, and seems in those superior regions somewhat less as tranger than the ab-

solutely ignorant. But, if this supposition be no more than a mere flight of fancy, yet in all cases the diligent and active scholar, who in fact supports that name, is always exercising his mental faculties in a superior degree: learns to survey, to comprehend, to combine more things together; raises himself in meditation farther above what is sensible and visible; habituates himself to more intellectual employments, and nobler pleasures; acquires a greater love for truth, than for all things else; finds in the research and knowledge of it the purest delight; feels more sensibly the vanity and emptiness of all earthly things; feels himself more forcibly attracted towards such as are infinite and eternal, towards God, the original source of all light and truth, and proceeds on his way to his superior state with brighter prospects and greater expectations. And surely this must be a suitable preparative to it?

If such be the case, if philosophical learning and science be an excellent habit and perfection of the human mind, if it procure a man real pleasure, and the noblest and purest kinds of pleasure, it promote by various ways, essentially promote the general welfare of society. If it is an efficacious preservative from superstition, and an equally efficient support to true religion, and a means of advancing it in the world, then is it incontestible, that it is of real and high value, that it may contribute, and actually does contribute, greatly to human happiness.

In conclusion I would say to the student, frequently balance what you know against what you do not and cannot know; what you know with assurance, against what is only hypothetical, and slightly probable; what you can actually make use of, against what is barely instrumental or matter of exercise, or even deception and error; what you may hope to carry with you into eternity, against what will be buried with you, and lost in the night of oblivion: and let all this teach you modesty and meekness. Let the sound intellect, the uncorrupted feelings of the heart, the wisdom that is grounded on experience, and shews itself in an active and busy life, have ample justice in your appreciation of the value of philosophical knowledge and scientific learning.

MECHANICS.

"Dr. Wallis defines mechanics to be the geometry of motion, a mathematical science, which shews the effects of powers, or moving forces, so far as they are applied to engines; and demonstrates the laws of motion."—*Harris*.

NATURAL PHILOSOPHY may be defined to be that which considers the powers and properties of natural bodies, and their actions on one another. Our knowledge of nature being found to result exclusively and entirely from experiment, the term Experimental Philosophy, has in modern practice been compounded with that of natural philosophy; and their definitions perfectly correspond. Natural philosophy is obviously a system, or an aggregate of several branches of knowledge, rather than a simple and uniform science of itself: and comprehends all those sciences which are named, and gathered in one enumeration beneath that designation at the commencement of this chapter, and will be found distributed through the following lessons. Chemistry and Mineralogy ought probably to be added to the number.

"The main business of natural philosophy," says Sir Isaac Newton, "is to argue from phenomena without feigning hypotheses, and to deduce causes from effects, till we come to the very first cause, which certainly is not *mechanical;* and not only to unfold the mechanism of the world, but chiefly to resolve these, and such like questions."

Matter is a substance, which by its different modifications becomes the object of our five senses: viz. whatever we can see, hear, feel, taste, or smell, must be considered as matter, being the constituent parts of the universe. Every being or substance that exists is made up of *matter*, whose properties we can investigate, though of itself we can know nothing. Now it is the property of some kinds of matter to act upon our senses immediately; of others, only by the perceptible effects they produce upon other bodies. We, therefore, arrange under the former, all sorts of matter as are capable of being seen, as wood, stone, &c.; and under the latter such species of matter as prove their existence only by their effects upon other bodies, as the atmospheric air, gases, &c.

The properties of matter explained in the following lessons

Sir Isaac Newton observes are the foundation of all philosophy, and extend to the minutest particles.

Newton's Princip., Book III. The third rule of reasoning in philosophy.

LESSON THE FIRST.

MATTER, AND ITS GENERAL PROPERTIES.

1. The science of *mechanics* treats of the laws, of the equilibrium, and motion of solid bodies: of the forces with which bodies may be made to act upon one another; and of the means by which these may be increased.

2. This science depends upon very simple principles, and may be resolved into the power which gravity and the laws of motion have on matter.

3. Matter is the general name of every thing that has length, breadth, and thickness; and its properties are solidity, divisibility, mobility, and inertia.

4. By *solidity*, a body will not permit any other substance to occupy the same place with itself, at the same time. No other body can occupy the part of space in which this book lies, without first removing the book.

Experiment.—A tube filled with water or air will not admit a plunger accurately fitted to it, without the water or air being first displaced.

5. By divisibility the parts of matter may be separated from each other without end.

Illustration.—Since matter cannot be annihilated by division, so we can never imagine it to be cut into such small particles, that any one of them shall not have an upper and under surface, which may be separated if we have instruments fine enough for the purpose. The parts of a body may be so far divided as not to be sensible to the sight; and by the help of microscopes we discover myriads of organized bodies totally unknown before such instruments were invented. A grain of leaf-gold will cover fifty square inches of surface, and contains two millions of visible parts: but the gold which covers the silver wire, used in making gold lace, is spread over a surface twelve times as great. From such considerations as these, we are led to conclude, that the division of matter

is carried on to a degree of minuteness far exceeding the bounds of our faculties. Mathematicians have shewn that a line may be indefinitely divided.

6. *Mobility* is that property of matter by which it is capable of being moved from one place to another.

7. *Inertia* is that property of matter by which it would always continue in the same state of rest or motion in which it is put, unless prevented by some external force.

ILLUSTRATION.—It is evident that matter, as a mass of iron or stone, can never put itself in motion. Bodies in motion, as a bowl on the ground, or a cannon ball going through the air pass from motion to a state of rest, either by the friction of the earth, by their own weight or gravity, or by the resistance of the air.

8. There are two kinds of attraction to be considered in mechanics; the attraction of cohesion, and the attraction of gravitation.

9. The attraction of cohesion is that by which the particles of matter are kept together, or which induces the parts of bodies to unite, when brought sufficiently near each other: by this principle bodies preserve their forms, and by this principle two drops of water, or globules of quicksilver, when brought sufficiently near each other, will run together.

10. The attraction of gravitation, or gravity, is that force by which distant bodies tend toward one another.

Example.—By this principle, a body dropped from the hand falls to the surface of the earth; and all terrestrial bodies tend towards the centre of the earth; and by it the planets tend towards the sun, and towards each other, as well as the sun to them.

11. The attraction of gravity decreases as the squares of the distance increase from the centre: that is, at *double* the distance from the centre, the force of gravity would be only *one-fourth* of what it is at the surface.

ILLUSTRATION.—The weight of bodies is owing to the principle of gravitation: a piece of iron, stone, or any other substance, that weighs at the surface of the earth, a pound or a hundred weight, would at double the distance from the

centre of the earth weigh only $\frac{1}{4}$lb. or $\frac{1}{4}$cwt.; and at three times the distance it would weigh only $\frac{1}{9}$th of a lb. or $\frac{1}{9}$th of a cwt.

QUESTIONS FOR EXAMINATION.

1. Of what does the science of mechanics treat?
2. Upon what does it depend?
3. What do you mean by matter?
4. Explain what is meant by solidity.
5. What is meant by the divisibility of matter?
Give the illustration.
6. What do you mean by the mobility of matter?
7. What is meant by the inertia of matter?
Give the illustration.
8. How many kinds of attraction are considered in mechanics?
9. Explain what is meant by the attraction of cohesion.
10. Illustrate the nature of gravitation.
11. By what law does the attraction of gravity decrease?
How is it illustrated?

LESSON THE SECOND.

MOTION.

1. Motion is a continued change of place, without which nothing can be produced or destroyed.

2. There are two kinds of motion, the *one* by which an entire body is transferred from one place to another: the *other* is the motion of the parts of bodies among themselves: by the first, a heavy body falls to the earth, a carriage or ship moves: by the second, plants and animals grow, and the compositions and decompositions of bodies take place.

3. To account for a body in motion there must be a cause; and the causes of motion, are, gravity, the action of men and other animals, of wind, water, steam, and the pressure of the atmosphere.

4. The velocity of motion is estimated by the time employed in passing over a certain space, or by the space passed over in a certain time: and to ascertain the degree of velocity, the space passed over must be divided by the time.

Example.—If a horse run 20 or 15 miles in an hour, then he goes with a velocity of one mile in 3 or in 4 minutes.

5. A body in motion must at every instant of time tend to some point. If it always tend to the same point, its direction is in a straight line, but if this point be perpetually changing, the motion will be curvilinear.

6. If a body is acted upon only by one force, in one direction, as in driving a ball along smooth ice, or by several successive forces in the same direction, as the motion given to a vessel on water by a man continually pulling it towards him, then the motion will be in the same direction.

7. If a body be acted upon by two or more forces in different directions at the same time, as it cannot move in all, it will move in a direction somewhere between them. The theorems relating to this are said to relate to the composition and resolution of forces.

Example.—When a ship is driven by wind due west, and by the tide due north, it will go neither to the west nor to the north, but if the forces be equal, it will be driven exactly north-west.

8. *Accelerated* motion is that in which the velocity is continually increasing.

Example.—A body falling to the earth from some high building, as the cupola of St. Paul's Church, affords an instance of accelerated motion, which is caused by the constant action of gravity.

9. Motion is said to be *retarded* when its velocity is continually decreasing.

Example.—If a cannon ball were fired perpendicularly upwards, its motion would be retarded every instant, till at length its direction being changed, it would fall again with an accelerated motion; and it would take precisely the same space of time in its fall as in the ascent.

10. The *velocities* of falling bodies, and also the *spaces* passed over by them increase as the odd numbers 1, 3, 5, 7, 9, &c. that is, a body would fall 16 feet in the first second; in the next it would fall three times 16, or 48 feet; in the third second it would fall five times 16, or 80 feet; in the fourth seven times 16, or 112, and so on.

11. The *whole spaces* passed over by a falling body, from the beginning of motion, will be as the squares of

the times, that is, as it falls 16 feet in the first second, it will fall through four times 16, or 64 feet in two seconds; nine times 16, or 144 feet in three seconds; and in four seconds it will fall through 16 times 16, or 256, and so on; because 4, 9, 16, 25, &c. are the squares of 2, 3, 4, 5, &c.

12. The *force* with which a body moves, or which it would exert upon another body opposed to it, is in proportion to the velocity multiplied by its weight: this force is called the *momentum.*

Example.—If two cricket balls of equal weight be so struck that the velocity of one be double that of the other, then the force of the swiftest will be double that of the slowest.

QUESTIONS FOR EXAMINATION.

1. What is meant by the term motion?
2. How many kinds of motion are there?
3. What are the causes of motion?
4. How is the velocity of motion estimated?

Give the example.

5. To what does a body in motion tend?
6. When is motion said to be in the same direction?
7. What will be the direction of a body in motion that is acted upon by two or more forces in different directions?

Give the example.

8. What is meant by accelerated motion?
9. When is motion said to be retarded?

Give the example.

10. What is the law with regard to the velocities of falling bodies, and also with regard to the spaces passed over by them?
11. What is the law with respect to the whole spaces passed over?
12. What is meant by the momentum of a body?

LESSON THE THIRD.

CENTRE OF GRAVITY.

1. The centre of gravity of a body is that point in which the whole force of its gravity or weight is united, and whatever supports that point, supports the body, therefore the whole weight of the body may be considered as centered in that point.

Example.—If I balance my pen or a cane on my finger, I know that the centre of gravity rests upon the finger.

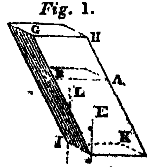
2. The common centre of gravity of two or more bodies is the point upon which they would rest in any position.

Example.—If I have two brass or marble balls connected together with a wire, and I am able to balance them by placing the wire in a certain position on my finger, I know the common centre of gravity of the two balls rests on the finger.

3. An imaginary line drawn from the centre of gravity of any body towards the centre of the earth is called the *line of direction*, because it is the line that the centre of gravity would describe, if the body were suffered to fall.

4. If the line of direction fall within the base upon which the body stands, the body cannot fall, but if it fall without the base, the body will tumble.

Fig. 1.



Examples.—The inclining body A B C D, fig. 1, whose centre of gravity is E, stands firmly, because the line of direction E D falls within the base: but if another body be placed upon it, the centre of gravity will be raised to L, and then the line of direction L D will fall out of the base, and the centre of gravity not being supported, the whole body will fall. In a coach or boat likely to be overset, the passengers should slip to the bottom, which lowers the centre of gravity, and diminishes the danger.

Hence buildings, as the tower A B, fig. 3, may lean many feet out of the perpendicular, and yet stand firm, provided a plumb-line, C c, suspended from C, the centre of gravity, fall within the base.

5. If a plane, C D, see fig. 2, p. 218, be inclined, on which a heavy body A, is placed, the body will slide down the plane, while the line of direction falls within the base, but if, as in B, the line of direction fall out of the base, the body will roll.

6. The broader the base of a body the firmer will it stand: thus the human body will stand

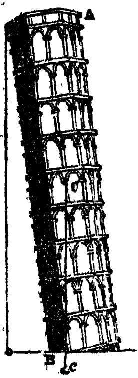


Fig. 3.

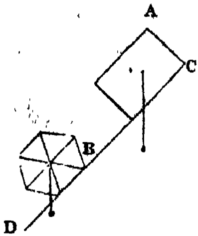


Fig. 2.

most steadily when the line of direction falls in the middle point between the feet.

Example.—Rope dancers perform their feats by knowing how exactly to keep the common centre of gravity of themselves, and their pole, just within the base.

QUESTIONS FOR EXAMINATION.

1. What is meant by the centre of gravity?
Give the example.
2. What is the common centre of gravity of two or more bodies?
3. What is meant by the line of direction?
4. In what case will a body stand, and when will it fall?
Give the examples.
5. In what case will a body slide, and when will it roll down a plane?
6. What makes a body stand very firmly?

LESSON THE FOURTH.

MECHANICAL POWERS.

1. The mechanical powers are simple engines that enable men to raise heavy weights, and overcome resistances, which they could not do with their natural strength.

2. Every machine is composed of one or more of the mechanical powers, of which there are six, viz. the lever, the wheel and axis, the pulley, the inclined plane, the wedge, and the screw.

3 A *lever* is an inflexible bar of wood, iron, &c. chiefly used to raise large weights, and it is supported by a prop or fulcrum, on which all the other parts turn, as the centre of motion. There are three kinds of levers, distinguished from one another by the different ways of using them.

4. A lever of the first kind is when the weight W, fig. 4, is at one end, the power P at the other, and the fulcrum D between the weight and power. A lever of the second kind is when the fulcrum A, fig. 5, is at one end, the power at the other, and the weight between them. The third kind of lever is when the weight is at one end, and the power between the fulcrum and weight.

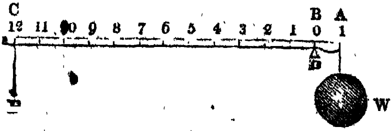


Fig. 4.

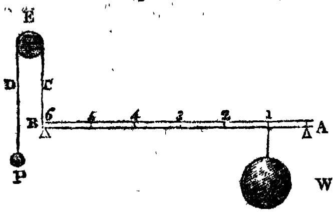


Fig. 5.

5. A poker stirring the fire is a lever of the first kind, for the bar of the grate is the fulcrum, the coals the weight to be moved, and the hand the power. Steelyards, scissars, pincers, snuffers, &c. are levers of the first kind.

6. Every door that turns on hinges is a lever of the second kind, the hinges are the fulcrum, or centre of motion, the door is the weight to be moved, and the hand in opening it is the power. An oar in the act of moving a boat is a lever of this kind, so is the rudder of a ship; also nut-crackers, and knives used in cutting chaff, &c.

7. A ladder to be raised by the strength of a man's arms is a lever of the third kind: the end fixed against the wall is the fulcrum, the top of the ladder may be regarded as the weight, and the power is the strength applied. The human arm in raising a weight is a lever of this kind.

8. A hammer drawing a nail is a lever of the first kind, but with a different application. The longer the handle of the hammer, compared with the shank or iron part applied to the nail, the easier the nail is drawn.

9. In all the mechanical powers it is a maxim that the

advantage gained is in proportion to the space passed over by the moving power.

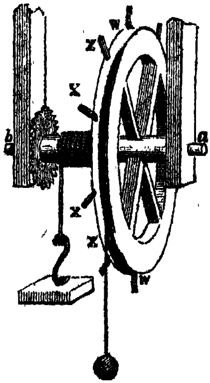


Fig. 6.

10. The *wheel and axis*, fig. 6, consists of a wheel W W on an axis *a b*, and the advantage gained is in proportion as the circumference of the wheel is greater than that of the axis. The projecting spokes X have the effect of increasing the diameter and circumference of the wheel, and of course of increasing the power.

11. Cranes of all kinds, windlasses, capstans, and those axles turned by means of winches, are all to be referred to the wheel and axis, of which they are so many species.

QUESTIONS FOR EXAMINATION.

1. For what are the mechanical powers used?
2. What are the mechanical powers?
3. What is a lever, and how many kinds of levers are there?
4. Explain the different kinds of levers.
5. What instruments are to be referred to the lever of the first kind?
6. What are to be referred to levers of the second kind?
7. What are to be referred to levers of the third kind?
8. To which of the levers is a hammer in the act of drawing a nail to be referred?
9. What is the general maxim with regard to the mechanical powers?
10. Of what does the wheel and axis consist?
11. What machines are to be referred to the wheel and axis?

LESSON THE FIFTH.

MECHANICAL POWERS.

1. The third mechanical power is the *pulley*, which is a small wheel turning on an axis, with a rope passing over it. It is used to change the direction of a weight; which may be raised to any height by a person not moving from his place.

2. Pulleys may be either fixed, as Z Z, or moveable, as X: the single fixed pulley, fig. 7, gives no mechanical advantage, but is only used to change the direction of a weight. The moveable pulley X, fig. 8, to which the weight W is attached, rises and falls with the weight, and the advantage gained by this pulley is as two to one; that is, a power *p* of 4lb. will balance a weight W, of 8lb.: for the power moves through twice as much space as the weight.

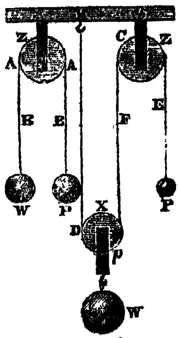


Fig. 7. Fig. 8.

3. The advantage gained by pulleys is found by multiplying the number of pulleys in the lower block by 2; that is, if instead of one pulley X, there were 3 or 4, there must, in that case, be 3 or 4 in the upper block, and the power gained would be as 6 or 8.

4. The fourth power is the *inclined plane*, which is made by planks, &c. laid in a sloping direction, on which large and heavy bodies may be more easily lowered or raised, than by a mere lift.

5. The wedge may be considered as two equally inclined planes.

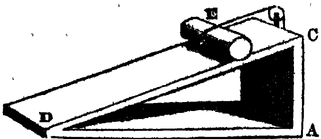


Fig. 9.

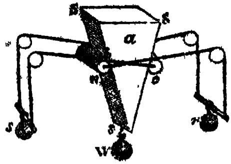


Fig. 10.

6. The advantage gained by an inclined plane is in proportion as the length of the plane C D, fig. 9, is

greater than the height AC: and the advantage gained by the wedge is in proportion as the length of the two sides S S, S S, see fig. 10, p. 221, is greater than the length of the back.

Explanation.—If C B, see fig. 9, p. 221, be three feet, and C A one foot, then a force of one pound will sustain the roller E of three pounds. And if the sides of the wedge, see fig. 10, be each 6 inches, and the back be 2 inches, then two weights, *r* and *s*, each 1lb. would sustain 12lb. placed on the back S S, of the wedge, or suspended by the hook *s*.

7. Chisels, hatchets, and other sharp instruments, which are sloped down to an edge on one side only, are to be referred to the inclined plane; and those instruments that are sloped down on both sides, act on the principle of the wedge.

8. The principal use of the wedge consists in its being urged by the stroke of a hammer, mallet, &c. and not by mere pressure. By repeated blows the wedge is used to split wood, rocks, &c.

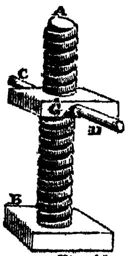


Fig. 11.

9. The last mechanical power is the *screw*, A B. fig. 11, which is always used with a lever C D, and which gains advantage in proportion as the circumference of the circle made by the lever is greater than the length between two threads of the screw.

10. The screw is used for pressing light bodies close together, as in presses for paper-makers, bookbinders, packers, &c. A common cork-screw in passing through the cork acts upon this principle.

11. When a screw acts in a wheel, it is called an *endless screw*.

12. In the application of the mechanical powers one-fourth, and often one-third, must be allowed to overcome the friction to which in practice they are all liable: that is, if 60 pounds are required to balance any weight, then 75 or 80 pounds will be required to put it in motion.

13. The capital advantages of the mechanical powers are, that by their means, we can raise and move from

place to place large weights, as blocks of stone; that we can give almost any direction to the moving power, and apply its action at a distance from the body to be moved.

QUESTIONS FOR EXAMINATION.

1. What is the fourth mechanical power?
2. How many kinds of pulleys are there?
3. How do you estimate the advantage gained?
4. For what is the inclined plane used?
5. What is the wedge?
6. How do you estimate the power gained by the inclined plane and wedge?

Give the explanation by means of the figure.

7. What instruments are to be referred to the inclined plane, and what to the wedge?
8. In what does the chief use of the wedge consist?
9. Which is the other mechanical power, and in what way does it gain advantage?
10. For what is the screw used?
11. What is meant by an endless screw?
12. What is to be allowed for friction in the application of the mechanical powers?
13. What are the capital advantages of the mechanical powers?

LESSON THE SIXTH.

MOVING POWERS.

1. The principal moving powers are the strength of men, horses, and oxen; the force of running water and of wind: the force of steam, and the weight of heavy bodies.

2. In clocks, jacks, &c. a weight is the first mover, which is easily applied; and its action is very uniform, but as the power requires to be frequently renewed, it is used only in slow movements.

3. The spring is a useful moving power, but requires also to be wound up occasionally, and it differs from the weight in this, that the action is never uniform, being strongest when most bent.

4. A *pendulum* is a heavy body suspended by a

small string, wire, &c. which is moveable on a centre; each swing of a pendulum is called a *vibration* or *oscillation*.

5. All the vibrations of the same pendulum, whether great or small, are performed in equal times.

6. The swinging of a pendulum is used for measuring time; one that swings seconds is little more than 39 inches long: and one that swings half seconds would be $\frac{39.2}{4} = 9.75$, &c., or a little more than $9\frac{3}{4}$ inches; and to vibrate once in two seconds it must be $39 \times 4 = 156$ inches.

7. The longer the pendulum, the slower are its vibrations; therefore, as heat lengthens the wire on which it swings, a clock is liable to lose time in summer, and to gain time in winter, when the cold contracts the wire.

QUESTIONS FOR EXAMINATION.

1. What are the principal moving powers?
2. What is the principle of a weight attached to clocks and jacks?
3. What are the properties of a spring?
4. What do you mean by a pendulum?
5. How are the vibrations of a pendulum performed?
6. For what is the swinging of a pendulum used?
7. What is the cause of irregularity in clocks?

HYDROSTATICS.

"Hydrostatics is the science of weighing fluids: and weighing bodies in fluids."—*Bentley.*

THE object of hydrostatics is the consideration of the properties and effects of fluids. By the term fluid is understood every body whose parts have so small cohesion, that the least force applied more in one direction than another, will produce a motion among them.

The cause of fluidity is not perfectly known. Some are of opinion that the particles of fluids are spherical, and in con-

sequence of their touching each other, in few points only, cohere very slightly, and easily slide over each other. But that the particles of fluids are of the same nature or figure as those of solids seems probable from the very frequent conversion of the one into the other. Though fluids are subject to the same laws of gravity with solids, yet their want of cohesion occasions some peculiarities. The parts of a solid are so connected together, as to form but one and the same whole; and their effort is, as it were, concentrated in a single point, called the centre of gravity. This is not the case with fluids: their parts gravitate independently of each other. And thus it is that the surface of a fluid contained in an open vessel is always level. It is a remarkable property of fluids, that they press not only in common with solids perpendicularly, but in every direction equally.

LESSON THE FIRST.

FLUIDS, THEIR PRESSURE AND LAWS.

1. Fluids are bodies, the parts of which yield to any impression: they are of two kinds, viz. *elastic*, as air, steam, and the different gases; and *non-elastic*, as water, oil, mercury, &c.

2. The science of hydrostatics treats of the weight, pressure, and other mechanical properties of *non*-elastic fluids, particularly of water.

3. Fluids, like solids, are subject to the laws of gravity; but the pressure of fluids is equal in every direction; viz. upwards and sideways as well as downwards, but that of solids is only towards the centre of the earth.

4. The surface of different portions of water which communicate with one another will be perfectly level while at rest.

Example.—If any number of tubes, joined together and communicating at the bottom, be placed in any direction, and water poured into one, it will be found that it stands at the same level in all.

5. On this principle water is carried in pipes to any distance, and raised to the same height in which it stands

in the reservoir: and springs will rise as high, or nearly so, as the sources from which they proceed.

6. The pressure of water is in proportion, not to the quantity, but to the perpendicular height at which it stands, and is exerted in every direction, viz. downwards, upwards, and sideways,

7. The horizontal bottom of a vessel sustains the pressure of a column of the fluid, the base of which is the bottom of the vessel, and the perpendicular height is equal to the depth of the fluid; therefore a given quantity of water may exert a greater or less force, according as the perpendicular height of it is greater or less.

8. Any quantity of fluid, however small, may be made to counterpoise any quantity however large, which is called the hydrostatical paradox.

Example.—Two upright vessels open throughout, united at the bottom; if the one hold a gallon, and the other only a pint, the fluid in the one will balance that in the other, and they will be level at the surface.

QUESTIONS FOR EXAMINATION.

1. What are fluids, and how are they distinguished?
2. What is the object of the science of hydrostatics?
3. To what laws are fluids subject, and how is the pressure estimated?
4. What is the rule for different portions of water that have a communication?

Give the example.

5. To what does this principle go?
6. How is the pressure of water estimated?
7. What pressure is sustained by the horizontal bottom of a vessel?
8. What is meant by the hydrostatical paradox?

Give the example.

LESSON THE SECOND.

SPECIFIC GRAVITIES.

1. Every body lighter than water, or that swims in it, will displace exactly as much of the water as is equal to its own weight.

2. Every vessel floating on the water displaces as much of the water as is equal to the vessel and lading in weight, and if more weight be added, the vessel will sink deeper.

3. Every body heavier than water, or that sinks in it, displaces so much water as is equal to the bulk of a body. On this principle are derived the specific gravities of bodies.

4. By the *specific gravities* of bodies are meant the relative weights which equal bulks of different bodies have to each other; these are found by weighing them in water.

5. If a body be suspended in water, it will lose as much of its weight as is equal to the weight of an equal bulk of water.

Example.—If a piece of glass weighs in air two pounds, and when suspended in water it weighs but one pound, it will be found that a quantity of water equal to the bulk of the glass weighs one pound also.

6. The specific gravities of bodies are *inversely* as the weights which they lose by immersion in water, that is, the body that is heaviest will lose least in water.

ILLUSTRATION.—Here are three bodies that will sink in water, viz. of coal, stone, and lead, and all of equal weights. They are of different sizes, the coal being the largest, and the lead the least, but as they lose weight in water in proportion to their bulks, the coal will lose the most and the lead the least; therefore the specific gravity being *inversely* as the weights they lose, the coal losing the most will be the lightest, and the lead losing the least will be the heaviest, and the stone will be intermediate between them.

7. The specific gravities of all solid bodies that sink

in water, may be found, first by weighing the body in the usual way, then in water, and dividing the first weight, by what it has lost in the water, the quotient is the specific gravity of the body.

Example 1.—A guinea weighs 129 grains; by being suspended in water it displaces as much water as is equal in bulk to the bulk of itself, which is equal to 7¼ grains: in other words it loses of its weight in water 7¼ grains: and 129 divided by 7¼ or in decimals $\frac{129}{7.25}$ gives 17.793, which proves the guinea to be almost eighteen times heavier than water.

Example 2.—This piece of brass weighs 1 ounce, or 240 grains. I suspend it in water and find it weighs only 210 grains, it has lost 30 grains: therefore 240 divided by 30 gives 8; of course the specific gravity of the brass is eight: or the brass is eight times heavier than water.

8. Pure rain-water in all parts of the world is of the same weight, and a cubical foot weighs 1000 ounces avoirdupoise: hence, if the specific gravities of bodies are known, their real weights are obtained.

Example.—A cubical foot of water weighs 1000 ounces; therefore a cubical foot of gold, like the guinea, would weigh 17.793 ounces, and a cubical foot of brass would weigh 8.000 ounces.

9. If the same body, as a piece of glass, or ivory, be weighed in different fluids, the specific gravities of the fluids will be lost.

Example 1.—This conical piece of glass suspended in water loses 803 grains; in milk it loses 831 grains; and in spirit of wine it loses 699 grains; therefore the specific gravities of water, milk, and spirit of wine, are 803, 831, and 699.

Example 2.—To find the real weight of the milk I say as $803 : 831 :: 1000 : \frac{831 \times 1000}{803} = 035$. That is, a cubical foot of the milk weighs 1035lb. or 35lb. more than the same quantity of water.

10. An *hydrometer* is an instrument for obtaining the specific gravity of bodies. It consists of a ball of glass or ivory, to which is attached a graduated stem, and as

it sinks more or less in the fluid, the fluid is lighter or heavier.

Example.—It will sink deeper in spirits of wine than in water, and deeper in water than in milk; and the degrees on the stem are so made as to give the specific gravities of the fluids at once.

QUESTIONS FOR EXAMINATION.

1. In what case will a body swim in water, and what proportion of the water will it displace?

2. What is the proportion of water that floating vessels displace?

3. What proportion of water does a body displace that *sinks* in water?

4. What is meant by the specific gravities of bodies?

5. How much weight does a body lose by being suspended in water?

Give the example.

6. How are the specific gravities of bodies estimated?

Give the illustration.

7. How are the specific gravities of solids found?

8. What is the weight of pure rain-water, and to what does this lead?

Give the example.

9. How do you obtain the specific gravities of fluids?

Give the example.

10. What is an hydrometer, and of what parts does it consist?

Illustrate this by an example.

HYDRAULICS.

ON THE SYPHON.

> "I see the rocky SYPHONS stretch'd immense,
> The mighty reservoirs of hardend'd chalk,
> Of stiff-compacted clay, capacious form'd."—*Thomson.*

HYDRAULICS is the science which teaches how to estimate the swiftness and force of fluids in motion.

A syphon, generally used for decanting liquors, is a bended pipe, whose legs are of unequal lengths. If a small bent tube, whose legs are of equal length, be filled with water and turned downwards, the fluid will not run off, but remain suspended therein, so long as it is held exactly level; but when an inclination is given to either leg, whereby the perpendicular altitude of one is in effect made shorter than the other, the water will flow from the lowest leg, and will continue to run till the vessel is emptied.

The theory of this is as follows: the air is a fluid, whose density near the surface of the earth is experimentally found to be that of water, at a medium, as 1 to 850; so that 850 gallons of air near the earth, weigh as much as 1 gallon of water. Now, according to the nature of all other fluid bodies, the air presses the surface of all things exposed to it every way equally. When, therefore, the legs of the syphon, equal in length are turned down, the weight of the atmosphere above being kept off by the machine, the under air bearing against and repressing the water, which tends to fall out of both of them with equal force, keeps it in suspense, and prevents its motion: but when, by inclining it to either side, we in effect shorten one of its legs, and lengthen the other in perpendicular altitude, the balance is destroyed, and the longest will preponderate.

Mercury may be drawn through a syphon in the same manner as water; but then the utmost height of the syphon must always be less than 30 inches, as mercury is nearly 14 times heavier than water. The syphon may be filled by pouring some of the fluid into it, or by placing the shorter leg into the vessel, and sucking the liquor through the longer leg. Syphons are extremely convenient for decanting liquors of various kinds, as they do not disturb the sediment.

The syphon may be disguised in such a manner as to produce many entertaining effects. It is frequently placed in a

cup, which is called Tantalus's cup, from the celebrated fable of Tantalus, who is represented by the ancients as suffering continual thirst, and though he is in the midst of water, is unable to assuage his thirst.

> "E'en in the circling floods refreshment craves,
> And pines with thirst amidst a sea of waves;
> And when the water to his lips applies,
> Back from his lips the treach'rous fluid flies."

In the cup there is a hollow figure of Tantalus, and if water is poured into it, so that it shall nearly reach to the lips of the image, the water immediately sinks, and is drawn off again. The truth is there is a syphon concealed within the image, and when the water is poured into the cup, so as nearly to reach the lips, the fluid is then raised above the bend of the syphon, which of course then begins to act, and the water is drawn off by the longer leg in the manner already described. Sometimes the syphon is concealed in the handle or in another part of the cup, in such a manner, that when a person raises it to his lips to drink out of it, the fluid which it contains shall be carried over the bend of the syphon, and it will then be drawn off by the longer leg, so that the person shall not only be disappointed of his draught, but will have his clothes well splashed, to the great amusement of the by-standers.

LESSON THE FIRST.

DESCRIPTION OF THE SCIENCE.

1. The science of hydraulics teaches us how to estimate the velocity and force of fluids in motion; and the means of raising them in pumps, &c.

2. Water can be only set in motion—(1.) By its own gravity; as when it is allowed to descend from a higher to a lower level: or (2.) By an increased pressure of the air: in the former case it will seek the lowest situation, in the latter it may be forced to almost any height.

3. If the pressure of the atmosphere be removed, water will rise above its natural level; as is the case in the action of the syphon.

4. A syphon is a bent tube, one of whose legs is longer than the other. The shorter leg is immersed in

the liquor that is to be drawn off, and the pressure of the air being taken from that part of the surface of the liquor within the tube, the liquor will rise above its natural level in the vessel, and will flow off through the longer leg.

5. A syphon may be used by filling it with water or some other fluid, stopping both ends with the finger, and in this state immersing it in the vessel: the fingers being removed, the water will flow out of the longer leg, by its own gravity, and afterwards by the pressure of the atmosphere on the liquor in the vessel.

6. Intermitting springs are caused upon the principle of the syphon.

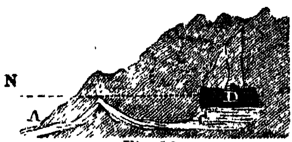


Fig. 12.

ILLUSTRATION.—In fig. 12, D is a reservoir under ground, which becomes filled with water by means of rain, snow, &c. draining through the earth. A B C is a sort of natural syphon which cannot begin to act till the water in the reservoir comes to the level N D, it then begins to run, and will continue to flow till the reservoir is empty. It will now stop till it is again filled up to the same level N D.

7. The velocity with which water spouts out at a hole in the side or bottom of a vessel, is in proportion to the square root of the distance from the hole below the surface of the water.

Example.—If at the distance of one foot from the surface the velocity is 1, another hole at four feet from the surface would give the velocity of 2, and at nine feet there would be a velocity of 3.

8. The pressure of water against the side of a vessel is as the square of the depth.

Example.—If a vessel be 3 feet deep and filled with water, the pressure upon the first foot will be 1, on the first and second it will be $1 + 3 = 4$, and on the whole side it will be $1 + 3 + 5 = 9$.

9. Water by its pressure may be conveyed over hills and valleys in bended pipes, to any height not greater than the level of the spring.

Examples.—Water is carried from the New River Head at Islington to all parts of London: and the water on the Hampstead and Highgate hills supply the houses in Kentish Town, and the adjacent villages, situated in the low grounds.

10. The *common pump*, fig. 13, sometimes called the sucking pump, consists of a pipe open at both ends, in which is a moveable piston that fits the bore exactly.

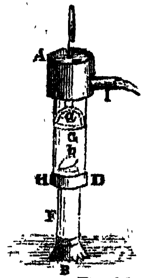


Fig. 13.

11. The *forcing pump*, fig. 14, consists of a pipe or barrel, a plunger, and two fixed valves, so disposed as to let the water rise freely, but to hinder its return.

Illustration.—In fig. 13 we have a representation of a common pump, and in fig. 14, one of a forcing pump. The end B stands in water, as a well, and at D H there is a valve *b*, which opens upwards, and one of the same kind also *a* in the piston G. The piston moves up and down in the pipe A D, but is air tight. If the piston G be forced down, the air between *a* and *b* will escape through *a*, but cannot return, so that in lifting up the piston there would be a vacuum under it; but the pressure of the atmosphere on the water in the well forces the water up into the pipe A D, and when the piston is forced down again, the water makes its way through *a*, and as it cannot return, it will, on lifting up the piston, be thrown out of the spout I, and the operation may be continued at pleasure.

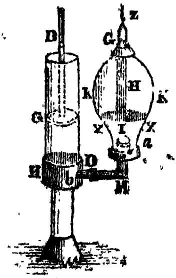


Fig. 14.

In the forcing pump there is a valve opening upwards at D H, which admits the water into the space G H, but the plunger G is solid, this when forced down drives the water through the pipe M, into the vessel K K, from whence the valve at *a* prevents its return. The pipe G H is fixed into the vessel so accurately that no air can escape, therefore the pressure of the air in K K, on the water X X, forces the water up a stream Z, and the more water is forced and the quicker, the higher will be the stream.

12. By the common pump the water can only be raised about 33 feet high, because the effect is produced by the pressure of the atmosphere; and the weight of a

column of the whole atmosphere is equal only to an equal column of water 33 feet high.

13. By means of forcing pumps water may be raised to any height above its own level, provided the machinery be sufficiently strong and powerful. On this principle engines for putting out fires, and for watering gardens are formed.

14. The steam-engine consists of a large cylinder or barrel, in which is fitted a solid piston like that of the forcing pump. The steam supplied from a large boiler close by, forces up the piston, and a valve is instantly opened, through which cold water rushes, condenses the steam, and causes the piston to descend by its own weight. By this alternate motion the grandest operations are performed.

QUESTIONS FOR EXAMINATION.

1. What does the science of hydraulics teach?
2. How is water set in motion?
3. In what case will water rise above its level?
4. What do you mean by a syphon, and how does it act?
5. Can it be used any other way?
6. What are intermitting springs?

Illustrate this by the figure.

7. What is the rule with respect to the velocity of water spouting out at a hole?

Give the example.

8. What is the rule for estimating the pressure of water against the side of a vessel?

Give the example.

9. How high can water be carried in pipes?

Mention the examples.

10. Of what does the common pump consist?
11. Of what does the forcing pump consist?

Look to the figures and explain the structure and operation.

12. How high can water be raised by a common pump, and why?
13. What are the necessary requisites of forcing pumps, and what engines are made on this principle?
14. Explain the principle of the steam engine.

PNEUMATICS.

OF THE PHENOMENA OF THE ATMOSPHERE.

"Diffusing gently its enlivening power,
The genial air, we all around us feel
Cheering, though unexplored by human sight."
Mrs. Barbauld.

THE word phenomena, which stands at the head of this lesson, is one of very frequent occurrence in scientific compositions; it means, simply, appearance. It is derived from the Greek verb PHAINOMAI, which signifies to appear; but it is generally used to indicate any striking or remarkable appearance. The atmosphere, as the student will find in the following lessons, means that mass of air which surrounds this globe. Various conjectures have been made with respect to the height of the atmosphere: and as we know to a certainty the relative weight of a column of the atmosphere by the height to which its pressure will raise water or mercury in any empty tube, so different calculations have been founded on these data, to ascertain its extent as well as its density at different heights. If the air of our atmosphere was, indeed, every where of a uniform density, the problem would be very easily solved. We should in that case have nothing more to do than to find out the proportion between the height of a short pillar of air, and a small pillar of water of equal weight; and having compared the proportion the heights of these bear to each other in the small, the same proportion will be sure to hold in the great, between a pillar of water 33 feet high, and a pillar of air that reaches to the top of the atmosphere, whose height I want to know. Thus for instance, we find that a certain weight of water reaches 1 inch high, and a similar weight of air reaches 72 feet high: this then is the proportion two such pillars bear to each other in the small. Now if 1 inch of water is equal to 72 feet of air, to how much air will 32 feet of water be equal? By the common rule of proportion I readily find that 32 feet or 384 inches of water will be equal to 331,776 inches, which makes something more than 5 miles; which would be the height of the atmosphere, was its density every where the same as at the earth, where 72 feet of air were equal to 1 inch of water.

But this is not really the case; for the air's density is not every where the same, but decreases as the pressure upon it decreases; so that the air becomes lighter and lighter the higher we ascend; and at the upper part of the atmosphere, where the pressure is scarce any thing at all, the air dilating in proportion, must be expanded to a surprising degree; and therefore, the height of the atmosphere must be much greater than has appeared by our calculation, in which its density is supposed to be every where as great as at the surface of the earth. In order, therefore, to determine the height of the atmosphere more exactly, geometricians have endeavoured to determine the density of the air at different distances from the earth. The following sketch will give an idea of the method which some geometricians have taken to determine this density, which is preparatory to finding out the height of the atmosphere more exactly.

Let us suppose a pillar of air to reach from the top of the atmosphere down to the earth's surface; and let us also suppose it marked like a standard by inches from the top to the bottom; let us still further suppose, that each inch of air, if not at all compressed, would weigh one grain. The topmost inch then weighs one grain, as it suffers no compressure whatever; the second inch is pressed by the topmost with a weight of one grain; and thus added to its own natural weight or density of one grain, now makes its density, which is ever equal to the pressure, two grains. The third inch is pressed down by the weight of the two inches above it, whose weights united, make three grains, and these added to its natural weight, give it a density of four grains. The fourth inch is pressed by the united weight of the three above it, which together make seven grains, and this added to its natural weight give it a density of eight grains. The fifth inch being pressed by all the former fifteen, and its own weight added, gives it a density of sixteen grains, and so on, descending downwards to the bottom. The first inch has a density of one, the second inch a density of two, the third inch a density of four, the fourth inch of eight, the fifth of sixteen, and so on. Thus the inches of air increase in density as they descend from the top, at the rate of one, two, four, eight, sixteen, thirty-two, sixty-four, and so on, which is called geometrical progression. Or if we have a mind to take this backwards, and begin at the bottom, we may say, that the density of each of these inches grows less upwards in a geometrical progression. If, instead of inches, wes uppose the parts into which a pillar of air is divided to be ex-

tremely small, like those of air, the rule will hold good in these as well as in those. So that we may generally assert, that the density of the air from the surface of the earth decreases in a geometrical proportion.

This being understood, should I now desire to know the density of the air at any certain height, I have only first to find out how much the density of the air is diminished to a certain standard height, and thence proceed to tell how much it will be diminished, at the greatest heights that can be imagined. At small heights the diminution of its density is by fractional or broken numbers. We will suppose at once then, for greater ease, that at the height of five miles, or a Dutch league, the air is twice less dense than at the surface of the earth: then at two leagues high, it must be four times thinner and less dense; and at three leagues, eight times thinner, and so on. Instead of Dutch leagues, suppose we took a German league of seven miles, and that it was four times less dense at the height of the first German league, then it would decrease in the same proportion, and be four times less dense than the first, at the second league, that is, sixteen times; and four times less dense than the second, at the third league, that is, sixty-four times; and four times less dense than the third at the fourth league, that is, two hundred and fifty-six times less dense than at the surface. In short, whatever decrease it received in the first step, it will continue to have in the same proportion in the second, third, and so on; and this, as I have said, is called geometrical progression.

Upon the same principle it was attempted to calculate the height of the atmosphere. By carrying a barometer to the top of a high mountain, the density of the air at two or three different stations was easily ascertained. But alas! so feeble are human efforts in endeavouring to comprehend and measure the works of the Great Creator, that this theory was soon demolished. It was found that the barometrical observations by no means corresponded with the density which by other experiments, the air ought to have had; and it was therefore suspected, that the upper parts of the atmosphere were not subject to the same laws or the same proportions as those which were nearer the surface of the earth. Another still more ingenious method was therefore devised.

Astronomers know, to the greatest exactness, the place of the heavens in which the sun is at any one moment of time: they know, for instance, the moment in which it will set, and also the precise time in which it is about to rise. However, upon awaiting his appearance any morning, they always see

the light of the sun before its body, and they see the sun itself some minutes sooner above the mountain top, than it ought to appear from their calculations. Twilight they see long before the sun appears, and that at a time when they know that it is eighteen degrees lower than the verge of the sky. There is then in this case something that deceives our sight; for we cannot suppose the sun to be so irregular in his motions as to vary every morning; this would disturb the regularity of nature. The deception actually exists in the atmosphere. By looking through this dense, transparent substance, every celestial object that lies beyond it is seemingly raised up, in some such manner as we see a piece of money look as if raised higher in a basin filled with water. From hence it is plain, that if the atmosphere was away, the sun's light would not be brought to view so long in the morning before the sun itself actually appears. The sun without the atmosphere, would appear all blazing in light the instant it rose, and leave us in total darkness the instant of its setting. The length of the twilight, therefore, is in proportion to the height of the atmosphere; or let me invert this and say, that the height of the atmosphere is in proportion to the length of the twilight. It is generally found by this means to be about forty-five miles high, so that it was hence concluded either that, that was the actual limit of the atmosphere, or that it must be of an extreme rarity, indeed, at that height.

The density of the air, however, depends not merely on the pressure it sustains, but on other circumstances; so that it varies even at the same height in different parts, and even in the same place at different times, as is seen by the mercury in the barometer rising to different heights according to the state of the weather. Heat in particular is a very powerful cause in rarefying the air. From this circumstance arises one of the most striking and formidable of the atmospherical phenomena, I mean the *wind*. Wind is nothing but a strong current or stream of air. Whenever, therefore, the air is heated by the sun, or by any other means, it will be rarefied, and less able to resist the pressure of the adjacent air, which will consequently rush in to restore the equilibrium, to speak in the technical language of philosophy, or in plain terms, to reduce the rarefied part to a uniform density with the other. This current of air is sensibly felt near the door of a glass-house, or wherever there is a large fire. A current of air is also to be perceived rushing through the key-hole, or any chink or crevice, into a heated room. This may serve to give the student a general idea of the causes of winds.

LESSON THE FIRST.

AIR AND ITS PROPERTIES.

1. The science of pneumatics treats of the mechanical properties of elastic fluids, such as their weight, density, compressibility, and elasticity.

2. The air which we breathe, and in which we live, surrounds the earth, and extends to a very considerable height above it on all sides.

3. The air together with the clouds and vapours floating in it, is call the atmosphere. The air is invisible because it is transparent.

4. The motion of the hand or of a stick, or whip, proves the existence of air as a resisting medium.

5. The air, like other bodies, has weight: for if a quart bottle be emptied of air and weighed, it will be found 16 or 17 grains lighter than it was before exhaustion: air is therefore between eight and nine hundred times lighter than water.

6. The weight of the air is variable; its changes and relative weights are ascertained by means of the barometer; for as the mercury is higher or lower, the air is heavier or lighter.

7. The air is heavier near the earth's surface, and lighter as we ascend, till at length, in the higher regions of the atmosphere, it is almost nothing at all.

8. The air being a heavy body, presses like other fluids in every direction upon whatever is immersed in it, and its pressure is equal to that of a column of quicksilver, about 29 or 30 inches in height.

9. The pressure upon a common sized man is equal to more than 30,000 lb. weight, because the surface of his body is about 14 square feet, or 2016 inches, and a column of quicksilver $29\frac{1}{2}$ inches high and 1 inch square, weighs 15 lb., therefore the whole pressure will be $2016 \times 15 = 30240$ lb.

10. The external pressure of the atmosphere would

be fatal to our existence if it were not balanced by an internal pressure which reacts against it.

11. The air can be compressed into a much less space than it naturally occupies.

12. The air is of an elastic nature, and the force of its spring is equal to the compressing force.

13. Air-pumps are machines for exhausting the air from certain vessels adapted to the purpose: and by means of these the mechanical properties of air are completely ascertained.

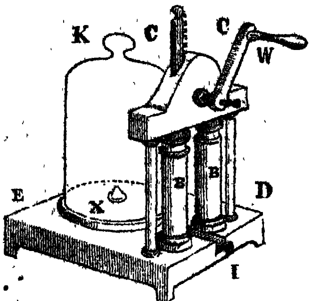


Fig. 1.

Explanation.—In fig. 1, we have the representation of a portable air-pump. B B are two brass barrels, each containing a piston with a valve working upwards. The pistons are worked by means of a winch W, which moves them up and down alternately. On the wooden frame D E is a brass plate ground perfectly flat and even, and a tube communicating with the two cylinders and the cock I, and opening into the centre of the plate X. K is a glass receiver to be exhausted of air, made to fit very accurately on the brass plate. Having shut the cock I, the pistons are worked up and down, and the air is suffered to escape by them at C C, but it cannot return. As the air is exhausted the receiver becomes immoveably fixed by the pressure of the external air, there being none within to counterbalance the pressure from without.

QUESTIONS FOR EXAMINATION.

1. Of what does the science of pneumatics treat?
2. How far does the air extend?
3. What is the atmosphere, and why is it invisible?
4. How is the existence of the air known?
5. Has the air weight, and how is it ascertained?
6. Is the weight variable, and by what means are its changes ascertained?
7. Where is the air heavier and where is it lighter?

8. What is the pressure of the air equal to?

9. What is the pressure of the air on a common sized man equal to, and why?

10. Why is not the external pressure of the air fatal to us?

11. Is the air compressible?

12. What is its elasticity equal to?

13. What are air-pumps used for?

Explain the structure of one.

LESSON THE SECOND.

EXPERIMENTS.

1. If a light substance, as a feather or slip of paper, and a heavy one, as a penny or a guinea, be dropped together from the hand, the metal will reach the ground first, which proves the resistance of the air: for

2. If a tall glass receiver be exhausted of its air, and in that state a guinea and a feather be dropped from the top, they will both reach the bottom at the same instant, because now there is no resisting medium through which they have to pass.

3. If air be 800 times lighter than water, then a cubical foot of air will be equal to 1000 ounces divided by 800, or equal to $1\frac{1}{4}$ ounce; therefore in a room 25 feet long, 14 feet wide, and 12 feet high, the air will weigh $25 \times 14 \times 12 \times 1\frac{1}{4}$* or 5.250 ounces, equal to 328lb.

4. If a cup of porous wood containing mercury be placed on the receiver of an air-pump, and the air be exhausted from under it, the external pressure of the atmosphere will force the mercury through the pores of the wood in a shower.

5. If the air be taken from the pores of a dry piece of wood, and if then it be held under mercury while

* The number of cubical feet contained in any space is found by multiplying the length, breadth, and height into each other, and the product 4200 multiplied by $1\frac{1}{4}$ (because each cubical foot of air weighs $1\frac{1}{4}$ ounce) gives the weight of the air in ounces = 5250.

the external air is admitted into the receiver, the mercury will be forced into all the pores.

6. If two brass hemispheres three or four inches in diameter, made for the purpose, be put together, and the internal air exhausted, the pressure from without will require 150lbs. to separate them. But if the external air be taken away they will separate of themselves.

7. If a square phial be exhausted of its air, while under a glass receiver, and the air suddenly let into the receiver, as it cannot get into the phial, it will dash the sides to pieces by the pressure of the air.

8. The elasticity of air is shewn by tying up a very small quantity of it in a bladder, and putting it under the receiver; when the receiver is exhausted the small quantity of air in the bladder will by its elasticity completely fill the bladder.

9. If a square phial filled with air, and accurately corked, so that none may escape, be put under a receiver from which the air is to be taken, then the elastic force of the air within the phial will break it to pieces.

10. I cover a small cork swimming on a vessel of water, with a glass goblet, which I force down perpendicularly through the water. The cork shews that the surface of the water within the goblet is not on a level with the surface without, which proves that air is a body which prevents water from occupying the same space with itself, and also that air is compressible, because the water ascends to a small height in the glass.

11. The smoke of a candle will ascend in the air, but in an exhausted receiver it will fall to the bottom, which shews that it generally ascends, because it is lighter than the air.

12. The sound of a bell may be heard while it is under a receiver full of air, but as soon as the air is exhausted there will be no more sound. Hence air is necessary to the propagation of sound.

13. Animals will not live, nor candles burn a single instant, in an exhausted receiver.

14. In condensed air the sound of a bell is much louder than in common air.

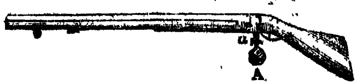

A

Fig. 2.

15. Air may be condensed into fifty thousand times less space than it usually occupies, and on this principle air-guns are constructed, which will kill birds and other animals at the distance of seventy or eighty yards. Fig. 2.

Explanation.—The air-gun in shape is like a common musket, but just below the lock is a copper ball, A, which screws off and on: when detached from the piece, it is charged by means of a syringe, with condensed air, and then screwed on again. The ball has a stop-cock at *a* which is shut when it is not on the gun. The bullet is rammed in the same way as we charge a musket, but it must fit the barrel exactly: the stop-cock is now turned, and by drawing the trigger, a small valve is opened at the bottom of the barrel, which suffers so much of the condensed air to escape as will force out the bullet to the distance of sixty or seventy yards. The ball A will contain eight or ten charges, and as there are two balls to a gun, one may be carried in the pocket to be made use of when the other is exhausted.

QUESTIONS FOR EXAMINATION.

1. What experiment proves the resistance of the air?
2. In what case will a heavy body and a light one fall with the same velocity?
3. How much does a cubical foot of air weigh, and how do you calculate the weight of air in any space, as a room?
4. By what means can mercury be forced through wood?
5. How can it be forced into the pores of wood?
6. What is the experiment with the brass hemispheres?
7. In what way can a square phial be broken by the external pressure of the air?
8. How is the elasticity of the air shown by a bladder?
9. How can a phial be broken by the elasticity of the air?
10. What experiment shews that air is a body, and is also compressible?
11. Why does smoke generally ascend?
12. Is air necessary to sound, and why?
13. Is air necessary to animal life and combustion?
14. Is sound louder in condensed or in common air?
15. Can air be very much condensed, and what instruments are constructed by condensed air?

Explain the construction and use of the air-gun.

LESSON THE THIRD.

ON THE ATMOSPHERE AND METEOROLOGY.

1. The atmosphere which surrounds the earth is essential to the existence of all animal and vegetable life; could it be withdrawn, the whole earth would be one continued scene of desolation: man, and other animals, would instantly die; vegetables would for ever cease; there could be no rain nor dew to moisten the ground, and the light of the sun and stars could render it but little advantage.

2. The air in motion is wind.

3. The mechanical force of the atmosphere, or wind, is of great importance in the affairs of men, who employ it in the motion of their ships, in turning their mills, in evaporation, and in a thousand other operations.

4. If the atmosphere were in every part equally dense, it would not be more than about five miles in height, because the weight of the atmosphere being equal to a column of water 33 feet high, and water being 800 times heavier than air, the height of the air would be 800×33 feet $= 26400$ feet $= 8800$ yards $= 5$ miles.

5. But as the density of air diminishes according to its height, it is found to be about 45 miles high.

6. The atmosphere has a refracting power by which we see the light of the sun some minutes before it actually rises above the horizon, and some minutes after it has sunk below it.

7. The atmosphere has also a reflective power, by which objects are enlightened on all sides, and without this property in the air we should only see those parts of objects on which the sun directly shines.

8. Atmospheric air consists principally of two other gases called oxygen gas and nitrogen gas, in the proportion of about one part of oxygen, and three of nitrogen gas.

9. It supports combustion and animal life, by the agency of the oxygen gas.

10. The barometer is intended to measure the different degrees of density of the atmosphere, and the mercury rises and falls according as the weight of the air is greater or less, but it seldom rises higher than 30½ inches, and is but rarely so low as 28½ inches.

11. The thermometer is designed to mark the changes in the temperature of the atmosphere with regard to heat and cold. Thermometers in this country are graduated upwards and downwards; 32° being put at the point of freezing, 55° is called temperate, and 76° summer heat. It has been known in this country as high as 94°, or 95°, and as low as 20° below 0, or 52° below the freezing point.

12. The hygrometer is an instrument contrived for measuring the degrees of moisture in the atmosphere; it is differently constructed: a very sensible one is simply a piece of whip-cord or catgut fastened at one end, and stretched over several pulleys, and at the other end are a little weight and index which move up and down a graduated scale.

13. Hempen cords, &c. shorten in damp weather, and lengthen when the air is very dry, and therefore according as the index is high or low the air is moist or dry, which is the theory of this kind of hygrometer.

14. The rain-gauge measures the quantity of rain that falls: it consists of a funnel 12 inches in diameter, attached to a tube 4 inches in diameter: in the tube is a floating graduated index which rises as the rain falls in the funnel and tube. By this instrument the 900th part of an inch of rain may be estimated.

15. One of a more simple construction consists of a funnel, the area of whose top is 10 square inches precisely, and the quantity of rain fallen is estimated by weight. Thus, if 16 ounces of rain are collected then $16 \times .173 = 2.768$ shews that the rain fallen is equal to rather more than 2¾ in depth.

16. By the agency of air, water is raised in vapour

from the earth, and forms *clouds*, which are seldom so high as four or five miles.

17. Clouds when sufficiently condensed either by the colder regions of the atmosphere, by electricity, or other causes, fall down in *rain*.

18. When the higher regions of the air are sufficiently cold, the vapours after condensation are frozen, and the particles descend in the shape of feathery flakes of *snow*.

19. When the drops of rain are frozen as they fall, it descends in the shape of *hail*.

20. *Dew* which falls in a summer's evening is part of the vapour raised in the day by the heat of the sun, which is condensed and falls down with the evening's cold. In cold nights the dew becomes frozen in the form of *hoar frost*.

QUESTIONS FOR EXAMINATION.

1. Of what use is the atmosphere?
2. What is wind?
3. To what purposes has the mechanical force of wind been applied?
4. If the atmosphere were everywhere equally dense, how high would it reach, and why?
5. How high is it actually?
6. What advantage is gained by the refracting power of the atmosphere?
7. What advantage is gained by the reflecting power of the atmosphere?
8. Of what does atmospheric air consist?
9. Which part of the air supports combustion and animal life?
10. For what is the barometer used?
11. For what is the thermometer designed?
12. For what is the hygrometer intended?
13. Explain the theory of the hygrometer:
14. Of what does the rain-gauge consist?
15. What is the construction of a more simple rain-gauge?
16. How are clouds formed?
17. How is rain produced?
18. Of what is snow formed?
19. What is hail?
20. What is dew, how is it formed, and what is it when frozen?

ACOUSTICS.

ON SOUND AND THE SENSE OF HEARING.

> "Mark how the spirits, watchful in the ear,
> Seize undulating sounds, and catch the vocal air."—*Blackmore.*

SOUND may be defined to be a perception of the soul communicated by means of the ear; or the effect of a collision of bodies, and a tremulous motion in consequence of that collision, communicated thence to the circumambient fluid, and propagated through it to the organs of hearing.

To explain this definition I must observe, that when obtuse bodies move in elastic fluids, they condense that part toward which they move, at the same time that the part from which they recede is rarefied. This condensation or rarefaction must produce an undulatory or vibrating motion in the fluid. Thus, if a body by percussion or otherwise, be put into a tremulous motion, every vibration of the body will excite a wave in the air, which will proceed in all directions so as to form a hollow sphere; and the quicker the vibrations of the body succeed each other, the less will be the distance between each successive wave. The sensation excited in the mind by means of these waves, which enter the ear and produce a like motion in a thin membrane, stretched obliquely across the auditory passage, is called sound. But the term is frequently used to imply, not only the sensation excited in the mind, but likewise the affection of the air, or of the sonorous body by which that sensation is produced. Thus we say, that a sound is in the air, or that a body sounds when struck, although the affection of the air or body is very different from the sensation.

That bodies move or tremble when they produce sound, requires no particular proof; it is evident in drums, bells, and other instruments, whose vibrations being large and strong, are therefore more perceptible: and it is equally clear, that a similar vibration is excited in the air, because this vibration is communicated through the air to other bodies that are adapted to vibrate in the same manner; thus bells, glasses, basins, and musical strings, will sound merely by the action propagated from other sounding bodies.

It is established as well by mathematical reasoning from the nature of an elastic fluid, as from experiment, that all

sounds whatever arrive at the ear in equal times from sounding bodies equally distant. This common velocity is 1142 English feet in a second of time. The knowledge of the velocity of sound is of use for determining the distance of ships, or other objects: for instance, suppose a ship fires a gun, the sound of which is heard five seconds after the flash is seen; then, 1142 multiplied by 5, gives the distance 5710 feet, or one English mile and 430 feet.

When the ærial waves meet with an obstacle which is hard, and of a regular surface, they are reflected, and consequently, an ear placed in the course of these reflected waves will perceive a sound similar to the original sound, but which will seem to proceed from a body situated in like position and distance behind the plane of reflection, as the real sounding body is before it. This reflected sound is called an echo.

This echo, or repercussion of sounds, is chiefly observable in smooth, tortuous, and hollow places, as in valleys, caves, and walls, especially in old vaulted buildings. An echo, therefore, as a pleasing, and very often wonderful circumstance, could not fail to enter into poetical descriptions, and to be the subject of fiction and personification. The Hebrews styled Echo, *the daughter*, and the Greeks and Latins, the *image of the voice*. Thus Virgil

> "Nor hollow rocks that render back the sound,
> And doubled *images of voice* rebound."—*Dryden.*

and Horace

> 'whose hallow'd name
> The sportive *image of the voice*,
> Shall in the shades of Helicon repeat,
> On Pindus, or on Hæmus ever cool."—*Francis.*

Milton, moreover, makes a noble poetical use of the philosophy of echoes in Adam's morning hymn.

> "Witness if I be silent, morn or even,
> To hill or valley, fountain, or fresh shade,
> Made vocal by my song, and taught his praise."

To return to the philosophy of the subject. The waves of sound being thus reflexible, nearly the same in effect, as the rays of light may be deflected, or magnified, by much the same contrivances as are used in optics. From this principle of reflection it happens that sounds uttered in one focus of an elliptical cavity are heard much magnified in the other focus; instances of which are found in several domes and vaults, particularly in the whispering gallery of St. Paul's

cathedral in London, where a whisper uttered at one side of the dome is reflected to the other, and may be very distinctly heard. On this principle also is constructed the speaking trumpet, which either is, or ought to be, a hollow parabolic conoid, having a perforation at the vertex, to which the mouth is to be applied in speaking, or the ear in hearing.

But to what purpose would be all these observations on the nature and properties of sound, if the human frame were not made capable of receiving it? How adorable then is the goodness of the Great Creator, in having not only disposed the air in such a manner that sound may be produced by vibrations, but in having given us an organ capable of receiving these sonorous vibrations.

The position of the ear is admirable; for it is placed in the most convenient part of the body, near the brain, the common seat of all the senses, to give the more speedy information, in a part where it can be best guarded, and in the neighbourhood of its sister sense, the eye, with which it has a peculiar and admirable communication by its nerves.

The first thing observable in the human ear is the auricle, or external ear, with its tortuous cavities, formed to stop and collect the sonorous undulations, to give them a gentle circulation and refraction, and to convey them to the concha, or large capacious round cell, at the entrance of the ear; and the great contrivance visible in the outward ear, is in nothing more apparent than in this circumstance, that they whose ears are cut off, have but a confused way of hearing, and are obliged either to form a cavity round the ear with their hand, or to make use of a hearing trumpet to supply the defect. The cartilaginous substance of the outward ear is, very obviously, another wise provision of the Great Creator.

In the interior part of this admirable organ we may observe, in the first place, the auditory passage curiously tunnelled and turned, to give sounds an easy passage, as well as a gentle circulation and refraction, and likewise to prevent their too furiously rushing in, and assaulting the more tender internal parts.

To prevent, moreover, the entrance of noxious insects which are apt to make their retreat in every little hole, Nature has secured this passage with a bitter nauseous substance, called the ear-wax, which is supplied by the glands appointed for that purpose.

The next principal thing to be observed, is the *membrana tympani*, or drum of the ear, with its inner membrane, the four little appendant bones, and the three inner muscles to

move them, and to adjust the whole system to the several purposes of hearing, to hear loud or soft, discordant or agreeable sounds.

The passage just behind the drum of the ear is called the vestibulum, being as it were, the anti-chamber or entrance to two other cavities. The first of these is called the labyrinth, and consists of certain semi-circular canals; and the second is called cochlea, from its resemblance to a snail shell. The labyrinth appears to have something of the mechanism and uses of a hearing trumpet; while the cochlea appears to be destined for the more delicate and refined uses of hearing, such as the forming and modulating of musical and harmonious sounds.

There is one particular contrivance of the nerves ministering to this sense, that I must not pass over; which is, that the branches of one of the auditory nerves spread partly to the muscles of the ear, partly to the eye, partly to the tongue and instruments of speech, and inosculated with the nerves that go to the head and breast. By these means there is an admirable and useful consent between the parts of the body; it being natural for most animals upon hearing any uncouth noise, to erect their ears, and prepare them to catch every sound; to open their eyes, those constant, faithful sentinels, to stand upon the watch: and to be ready with the mouth to cry out and utter what the present exigency may suggest. And this is accordingly usual for most animals, when surprised or terrified by any frightful noise.

Such is the nature and properties of sound, and such the admirable structure and uses of the ear. If it be asked why, when a word is pronounced it excites a certain idea, and not a simple tone? or how a sound can act upon the soul, and produce so many different notions? we are obliged, in this respect, to confess our absolute ignorance. We know enough, however, to be assured that the ear is one of the most convincing proofs in nature of the divine wisdom and goodness; and well may we exclaim with the devout David, "Such knowledge is too wonderful for me: it is high and I cannot attain unto it. But I will praise Thee, O Lord, for I am fearfully and wonderfully made."

ACOUSTICS.

ANALYSIS OF THE SCIENCE.

1. Acoustics is a science which instructs us in the nature of sound. It is divided into *diacoustics*, which explains the properties of those sounds that come directly from the sonorous body to the ear; and *catacoustics* which treats of reflected sounds.

2. Most sounds that affect us are conveyed to the ear by means of the air: but water is a good conductor of sound: so also are timber and flannel.

EXPERIMENTS.

(1.) A bell rung under water returns a tone as distinct as if rung in air.

(2.) If you stop one ear with a finger, and the other by pressing it close to a long stick or piece of deal board, and a watch be held at the other end of the wood, the ticking will be heard, be the stick or board ever so long.

(3.) If you tie a poker or any piece of metal on to the middle of a strip of flannel about two or three feet long, and then press with the thumbs or fingers the ends of the flannel into your ears, while you swing the poker against an iron or steel fender, you will hear a sound like that of a heavy church bell.

3. A body while sounding is in a state of vibration, which it communicates to the surrounding air, the undulations affect the ear, and excite in us the sense of sound.

4. Sound travels at the rate of 1142 feet in a second, or about 13 miles in a minute. This is the case with all kinds of sounds: the softest whisper flies as fast as the loudest thunder.

5. The velocity of sound has been applied to the measurement of distances.

EXPERIMENTS.

(1.) A ship at sea in distress fires a gun, the light of which is seen on shore 20 seconds before the report is heard, therefore it is known to be at the distance of 20 times 1142 feet, or little more than 4½ miles.

(2.) I see a vivid flash of lightning, and in three seconds I hear a tremendous clap of thunder, I instantly know the thunder cloud is only about two-thirds of a mile distant, I should therefore retire instantly from any exposed situation.

(3.) The pulse of a healthy person beats about 76 times in a minute, if therefore between the flash of lightning and the thunder I can feel 1, 2, 3, 4, &c. beats of my pulse, I know the cloud is 900, 1,800, 2,700, 3,600 feet from me.

6. Sound, like light, after it has been reflected from several places, may be collected into one point as a focus, where it will be more audible than in any other part; and on this principle whispering galleries are constructed.

7. Speaking trumpets and those made to assist the hearing of deaf persons, depend on the reflection of sound from the sides of the trumpet, and also by its being confined and prevented from spreading in every direction.

8. A speaking trumpet, to have its full effect, must be directed in a line towards the hearer: the report of a gun or cannon is much louder when fired towards a person, than one placed in a contrary direction.

9. An echo is the reflection of sound striking against a surface fitted for the purpose, as the side of a house, a brick wall, hill, &c.

EXPERIMENTS.

(1.) If a person stand about 65 or 70 feet from such a surface, and perpendicular to it, and speak, the sound will strike against the wall and be reflected back, so that he will hear it as it goes to the wall, and again on its return.

(2.) If a bell situated in the same way be struck, and an observer stand between the bell and the reflecting surface, he will hear the sound going to the wall, and also on its return.

(3.) If the sound strike the wall obliquely, it will go off obliquely, so that a person who stands in a direct line between the bell and the wall will not hear the echo.

10. The variety of sounds depends on the frequency of the vibration, on the quantity and force of the vibrating particles, and on the simplicity of the sounds;

hence are derived the height, strength, and quality of sounds.

11. *Music* is any succession of sounds, that excites in a well disciplined ear certain agreeable sensations. Sound is therefore the subject matter of music, and it is harmony that makes sounds musical.

12. *Harmony* is the coincidence of two or more sounds, which by their union afford to the mind pleasure and delight.

13. Two strings of equal length, tension, and thickness, by performing their vibrations together, will sound the same note, or be in unison. Two pipes of the same length and diameter will agree in the same manner.

Explanation. In the case of the strings, the air is struck by the body, and the sound is excited by the vibrations: in that of the pipes the body is struck by the air, but as action and re-action are equal, the effect is the same.

14. Large instruments and long strings produce grave or deep tones: small instruments and short strings produce acute and high tones.

Examples.—Let a musical string of any length be divided into two equal parts by a bridge in the middle: and the sound of each half is eight notes, or an octave, higher than the tone of the whole string.—Organ pipes produce grave or acute tones in proportion to their length and size. It is the shortest string of a harpsichord which yields the highest notes.

QUESTIONS FOR EXAMINATION.

1. What is meant by the science of acoustics, and how is it divided?

2. How are sounds conveyed to the ear?

Give an account of the experiments.

3. How is the sense of sound excited?

4. At what rate does sound travel?

5. To what purpose has the velocity of sound been applied?

Give an account of the experiments.

6. Can sound be collected in a focus?

7. On what principles do speaking trumpets depend?

8. How must a speaking trumpet be situated to produce the full effect?

9. What is an echo?
Give an account of the experiments.
10. On what does the variety of sound depend?
11. What is meant by music?
12. What is harmony?
13. When will two strings and two pipes be in unison? Give the explanation.
14. Which instrument produces deep, and which acute tones? Produce the examples.

OPTICS.

ON VISION.

"With thought from prepossession free, reflect
On solar rays, as they the light respect.
The beams of light had been in vain display'd,
Had not the eye been fit for vision made:
In vain the Author had the eye prepar'd
With so much skill, had not the light appear'd."

Blackmore.

If the construction of the universe were not so evident a proof of the existence of a supremely wise and benevolent Creator, as to render particular arguments unnecessary, the structure of the eye might be offered as one, by no means the least. This instance, amongst numberless others, demonstrating that the most exquisite performances of art, are infinitely short of those which are continually produced by the Divine Mechanic.

Of all the senses the sight is that which furnishes the soul with the quickest, most extensive, and most varied perceptions. It is the fertile source of the richest treasures of imagination, and it is to that principally, that the soul owes the ideas of beauty, and of that varied unity that enchants it.

"Our sight," indeed, as observed by an admirable writer, "is the most perfect and delightful of all our senses. It fills the mind with the largest variety of ideas, converses with its objects at the greatest distance, and continues the longest in action, without being tired or satiated with its proper enjoyments. The sense of feeling can indeed give us a notion of extension, shape, and all other ideas that can enter at the

eye, except colours; but, at the same time, it is very much straitened and confined in its operations, to the number, bulk, and distance of its particular objects. Our sight seems designed to supply all these defects, and may be considered as a more delicate and diffusive kind of touch, that spreads itself over an infinite multitude of bodies, comprehends the largest figures, and brings into our reach some of the most remote parts of the universe."

The eye is composed of several tunics, or coats, one within the other, and is filled within with transparent humours of different refractive densities. The external tunic, called the *sclerotica*, is white on the anterior part, except a circular portion immediately in front, which is transparent, and more convex than the rest of the eye: this transparent part is called the *cornea*. Immediately adherent to the *sclerotica* within, is the *chorides*, or *unea;* which, at the circumference of the *cornea*, becomes the *iris*, being expanded over great part of its surface, though not contiguous to it. The *iris* is composed of two kinds of muscular fibres; the one sort tend like the radii of a circle towards its centre, and the others form a number of concentric circles round the same centre. The central part of the *iris* is perforated, and the orifice which is called the *pupil*, is of no constant magnitude, for when a very luminous object is viewed, the circular fibres of the *iris* contract and diminish its orifice; and, on the other hand, when objects are dark and obscure, the radial fibres of the *iris* contract; and enlarge the pupil, so as to admit a greater quantity of light into the eye. The *iris* is variously coloured in different persons, but according to no general rule. In general, they whose hair and complexion are light-coloured have the iris blue or grey; and on the contrary, they whose hair and complexion are dark, have the iris of a deep brown. But what specific difference this may occasion in the sense, or whether any at all, is not discoverable. Within the *unea* is another membrane, which at the circumference of the *cornea* becomes fibrous, and is called the *ligumentum ciliare*. This ligature is attached to the circumference of a double convex lens, whose axis corresponds with the centre of the pupil; and which, by means of the fibres, can be altered, in a small degree, in position, and perhaps in figure. This lens is termed the crystalline humour; and is included in a very strong and transparent membrane called the *arachnoides*. Between the crystalline humour and the *cornea* is contained a clear transparent fluid called the aqueous humour: and between the crystalline humour and the

posterior part or bottom of the eye, is included another clear transparent fluid, which is called the vitreous humour. The refractive density of the crystalline is greater than those of the luminous that surround it. On the side next the nose, a nerve is inserted in the bottom of each eye, about twenty-five degrees from the axis of the crystalline, which, after entering the eye, is spread into an exceeding fine coat of net-work termed the *retina*. Lastly a very black mucus or slime, is spread over all the internal parts of the eye, that are not transparent, except the anterior part of the *iris*, which as I have before observed is coloured.

From this account of the structure of the eye, I shall proceed to that of vision, or the act of perceiving external objects by the organs of sight. And this is well defined to be a sensation, by which, from a certain motion of the optic nerve, made in the bottom of the eye by the rays of light emitted or reflected from objects, and hence conveyed to the common sensory in the brain, the mind perceives the luminous object, its quantity, quality, figure, &c. And thus all modern philosophers agree, that vision is performed by rays of light, reflected from the several points of objects received in at the pupil, refracted and collected in their passage, through the coats and humours before-mentioned, to the retina, and thus striking, or making an impression on so many points of it; which impression is conveyed to the brain, &c., by the correspondent capillaments, or fibres, of the optic nerve.

The cornea, or second coat of the eye, being of a convex figure, performs the office of a glass lens. To illustrate this by a familiar example: put a glass lens into a hole made in the window shutter of a dark room; present a pasteboard to this lens, and you will immediately have a picture, in which all the objects without will be painted to the greatest precision, and according to all the rules of the most exact perspective. It will be like a moving picture whenever these objects move. You will then see rivers rushing down from the tops of mountains, and meandering in the plains; birds hovering in the air, fishes sporting on the surface of the water; flocks frisking in the meadows; and in fine all the possible varieties of prospect.

Substitute instead of the lens, the real eye of an ox, newly stripped of its leguments, and you will have the same picture on the membrane which covers the bottom of it; but all the figures will be painted in a much smaller size. You can never be tired of admiring the extreme delicacy of this piece

of miniature, and you will be astonished to behold a field fifteen or twenty miles square, exactly delineated on a piece of vellum of a few lines in length.

The structure of the eye of an ox is the same, with respect to the essential parts of it, as that of ours; and thus the mechanism of vision is explained. The humours of the eye are the lens of the camera obscura; the retina is the pasteboard. The black skin which hangs within the pupil performs the office of a shutter that excludes the light, it extinguishes the rays whose reflection would render the image less distinct. The pupil, by contracting or dilating itself in proportion to the strength of the light, moderates the action of the rays on the retina; and the nerve placed behind this, communicates to the brain, as before observed, the various concussions it receives, and to which various perceptions correspond.

In the theory of vision there are many curious phenomena, which have exercised the ingenuity of the most learned men. Whence comes it, for instance, that all external objects are painted inverted on the retina, and that we see them, nevertheless, in their real situation? Whence is it that objects of the greatest magnitude are delineated on the eye with extreme minuteness, and yet we perceive every thing in its proper size? Whence is it that if we look down from the top of St. Paul's cathedral, we see beneath us the many thousand houses of this great metropolis, each painted so exactly in our eye in a space hardly three times larger than the head of a pin? So many millions of rays enter by a very small aperture; they are united on the retina at the bottom of the eye, without confusion, and constantly preserving the same order which the points of the objects had, that emitted them. Let us ascend a high rock, and observe a fleet in full sail at sea; let us contemplate the sea itself, and what millions of waves may be discovered! Each of these, nevertheless, reflects masses of rays upon our eye, the size of which is so minute. In an extensive country prospect, every tree, and even every blade of grass emits its rays; without which it would be impossible for us to perceive the uninterrupted verdure of all the fields beneath us. Is it not wonderful too, that we do not see objects double; and that although we have two eyes, each object still appears but one.

But there is another circumstance to excite our admiration. The objects we behold are not visible to us alone: we have just observed with astonishment, the number of rays they send on a space so small as that occupied by the pupil of the eye. They all send as many more to every part of

the mass of air that surrounds them. Wherever, therefore, we may remove, new rays replace the first, and render the same objects visible to us that we had seen in our former situation. All the rays necessary to effect this had existed before, and waited only for eyes. But the rays admitted into the eye are not all equally efficacious. Besides these, there are innumerable others, which being much weaker, are effaced by the splendour of the first, but which are constantly ready to perform the same functions if necessary. Such are the wonderful phenomena of vision!

The great philosopher of antiquity, in his treatise *de Natura Deorum*, was sensible of the wisdom and contrivance displayed in the construction of the eye. "What artificer," says he, "but Nature, whose direction is incomparable, could so artfully have formed the senses? She has covered and invested the eyes with the finest membranes, which she has made transparent, that we may see through them, and firm in their texture, to preserve the eyes. She has made them slippery and moveable, that they might avoid what would offend them, and easily direct the sight wherever they will. The point of sight, which is called the pupil, is so small, that it can easily shun whatever may be hurtful to it. The eyelids, which are their covering, are soft and smooth, that they may not injure the eyes, and are made to shut at the apprehension of any accident, or to open at pleasure; and these movements Nature has ordained to be made in an instant. They are fortified with a sort of palisade of hair, to keep off what may be noxious to them when open, and when sleep closes them, to be a fence to their repose. Besides, they are commodiously defended by eminences on every side: for on the upper part, the eye-brows turn aside the sweat that falls from the forehead; the checks beneath, having a little rising, protect the lower; and the nose is placed between as a wall of separation."

LESSON THE FIRST.

OF DEFINITIONS NATURE AND PROPERTIES OF LIGHT.

1. *Optics* is the science of vision, and it includes Dioptrics, Catoptrics, and Chromatics.

2. *Dioptrics* is the science of refracted vision, or that which considers the several refractions of light in pass-

ing through different media, as air, water, glass, &c. and especially lenses.

3. *Catoptrics* is the science of reflected vision, and explains the appearances of objects seen by the reflection of polished surfaces.

4. *Chromatics* is that part of the science of optics which explains the several properties of the colours of light, and of natural bodies.

5. Light consists of an inconceivably great number of particles flowing from a luminous body in all directions. A *ray of light* is the motion of a single particle, which is represented by a straight line.

6. Light travels from the sun to the earth in about eight minutes, or at the rate of two hundred thousand miles in a second of time.

Explanation.—The velocity of light was discovered by observing the eclipses of Jupiter's satellites, which are found to happen 16 minutes later than the calculated time, if the earth is in that part of the orbit which is farthest from Jupiter, than if it were in the opposite part of the heavens: that is, the light from the satellites of Jupiter is 16 minutes in travelling over the length of the earth's orbit, or 190 millions of miles.

7. The particles of light move in all directions without the least disturbance, and hence it is inferred they must be inconceivably small.

EXPERIMENTS.

(1.) Make a small pin-hole in a piece of brown paper, and through this may be seen at once a great variety of objects, as trees, houses, &c. Now, as we see objects only by the particles of light reflected from them to the eye, it is evident that these particles must cross each other in passing through the hole in the paper, which they do without being in the least disturbed by the motion.

(2.) A candle placed on an eminence in a dark night may be seen a mile or two all round, which proves that light moves in all directions, and as a single candle may be seen in all that space in an instant after it is lighted, we may be sure the particles must be very small.

8. Light always moves in a straight line.

ILLUSTRATION.—(1.) Look at an object through a straight tube and you see the object by means of the rays of light flowing from it, but point a bended tube direct to the sun, and its rays will not pass to the other end.

(2.) The shadows which are cast by opaque bodies, as a building, &c. prove also that the rays of light move in a straight line only.

9. The particles flowing from a luminons body, as the sun, or a candle, give us the idea of light; these particles falling on bodies, as the furniture of a room, and reflected to our eyes, furnish us with the idea of those bodies.

Experiment.—Go into a darkened room, and you have no idea what that room contains; but admit the rays of light, these at the same instant, owing to the velocity with which they travel, flow upon all the bodies in the apartment, and are reflected to the eyes, thereby exciting in the mind the idea of these bodies.

10, Every part of a visible body reflects the rays of light in all manner of directions. For let a person stand where he will, he sees every part of the surface of a body which is toward him, when no intervening object obstructs the rays.

11. The intensity or degree of light decreases as the square of the distance from the luminous body increases.

ILLUSTRATION.—(1.) If I stand one yard, two yards, three yards, &c. from a candle, the proportion of light will be as one, one-fourth, one-ninth; that is, at two yards distance, I shall have only the fourth part of the benefit of the candle that I should have at a yard's distance only; and at three yards distance the benefit would be only one-ninth as great as at one yard distance only; at four yards it would be only one-sixteenth, and so on.

(2.) The Herschel planet is about twenty times as far from the sun as the earth; it will therefore enjoy 20×20 times, or 400 times, less of the benefits of light and heat than we experience.

QUESTIONS FOR EXAMINATION.

1. What is meant by optics?
2. What do you mean by dioptrics?
3. What is meant by catoptrics?

4. What is meant by chromatics?
5. Of what does light consist, and what is meant by a ray of light?
6. At what rate does light travel?
Explain how that was discovered.
7. How do the particles of light move?
Mention the experiments that prove this.
8. Does light move in any other than a straight line?
9. How do you obtain the idea of external objects?
10. In what way do visible bodies reflect light?
11. What is the law with respect to the intensity or degree of light?
Give the illustrations.

LESSON THE SECOND.

LIGHT.

1. A number of rays of light proceeding from a point is called a pencil of rays.

2. By a *medium* is meant any pellucid or transparent body which suffers rays of light to pass through it, as water, glass, air, &c.

3. Parallel rays are such as move always at the same distance from each other.

4. If rays continually recede from each other, from any given point, they are said to diverge.

5. If they continually approach each other, as in moving to a point, they are said to converge, and the point at which converging rays meet is called the *focus*.

6. The point to which they tend, but which they are prevented from reaching by some obstacle, is called the *imaginary focus*.

7. While rays of light continue in any medium of an uniform density, as in air, or water, they proceed in a straight line; but if they pass from a medium of one density, as air, to one of another, as glass or water, they will be bent out of the straight line, unless they pass in a perpendicular direction.

8. When rays of light passing obliquely out of one

medium into another, are bent out of the straight line, they are said to be *refracted.*

Example.—An oar in the water will exemplify this: the rays of light proceeding from the handle come straight to the eye, but those from the other end, which is under the water, are bent or refracted in their passage to the eye, and the oar appears crooked. The same may be seen of any straight stick or piece of wood partly plunged in water, not in a perpendicular situation.

9. Rays of light passing from a rarer to a denser medium are always refracted to a perpendicular.

EXPERIMENTS.

(1.) Let the rays of the sun passing through a small hole in a shutter, proceed through a decanter or upright glass jar of water, and they will be bent out of the straight line, and will fall to points nearer the shutter than they would if the water was away.

(2.) Let the rays fall in an empty pan and mark where they come, then without moving the vessel, put some water in it, and the rays will fall nearer the side of the pan than they did before.

(3.) If a piece of looking-glass be laid at the bottom of the vessel the light will be reflected from it, and will suffer the same refraction in going out as in coming in, only in a contrary direction.

10. Rays of light passing from a denser to a rarer medium will be refracted farther from the perpendicular.

EXPERIMENTS.

(1.) Stick with a piece of wax a shilling on the bottom of an upright pan, and let a spectator move back till he lose sight of the shilling, then fill the pan with water, and he will see it again, though neither he nor the shilling has moved from their places, which shews that in passing through the denser into a rarer medium, the rays proceeding from the object are bent farther from a perpendicular which might be raised in the centre of the vessel.

(2.) Take a glass goblet half full of water, throw a shilling into it, then put a plate over it, and holding the plate fast, invert the whole pretty quickly, and there will appear to be two pieces of money, viz. a shilling and half a crown: the former is seen by refraction through the water, the latter by the rays after refraction at the surface.

11. A *lens* is a glass ground into such a form as to collect or disperse the rays of light that pass through it. There are various kinds of lenses named according to their forms.

12. A *plano convex* lens has one side flat and the other convex; and a *plano concave* is flat on one side, and concave on the other.

13. A *double convex* lens is convex on both sides: and a *double concave* is concave on both sides.

14. A *meniscus* lens is convex on one side, and concave on the other: a watch glass is of this kind.

15. A *prism* is a triangular piece of glass which has the power of separating the rays of light into their component parts.

QUESTIONS FOR EXAMINATION.

1. What is meant by a pencil of rays?
2. What is meant by a medium?
3. What are parallel rays?
4. When are rays said to diverge?
5. When are they said to converge, and what is the focus?
6. What is meant by the imaginary focus?
7. In what case do rays of light proceed in a straight line, and in what case are they bent?
8. When are rays of light said to be refracted?
9. When are rays refracted nearer *to* a perpendicular? Give an account of the experiments.
10. When are rays of light refracted farther *from* a perpendicular? Mention the experiments that shew this.
11. What is a lens, and how are lenses named?
12. What are plano-convex, and plano-concave lenses?
13. What are double convex and double concave lenses?
14. What is meant by a meniscus lens?
15. What is a prism, and for what is it used?

LESSON THE THIRD.

REFRACTION.

1. If parallel rays fall upon a plano-convex lens, they will be so refracted as to unite in a point behind, called

the focus, which point is at a distance equal to the *diameter* of the sphere of which the lens is a portion.

2. If parallel rays fall on a double convex lens they will be refracted and unite at a distance equal to the radius of a sphere, of which the lens is a portion.

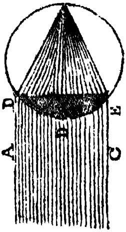


Fig. 1.

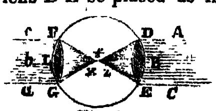


Fig. 2.

Illustration.—The rays, A C, fig. 1, falling upon the plano-convex lens, D D E, will be refracted and unite at F: but the rays *a b c* falling on the double convex lens F L G, fig. 2, will unite in *f*, where they will cross, and if another lens D E be placed as in the figure to receive them, they will go out of that lens in the parallel direction A B C. It must be observed that the lower ray *a*, in going in, will be the upper one A in going out; and the upper one *c*, in going in, will be the lowermost C in going out.

3. All the rays of the sun that pass through a lens are collected in the focus; and the force of the heat at the focus is to the common heat of the sun, as the area of the glass is to the area of the focus.

Illustration.—If the area of the lens F G be three inches, and that of the focus only one-fourth of an inch, then as the areas of all circles being as the squares of their diameters, they will be to one another $1^2 : 12^2$, or $1 : 144$, that is the heat at *f* will be 144 times greater than it is at F G. The reason is obvious, for all the rays *a b c* are collected in a point *f*.

4. All common burning glasses are double convex lenses, which is the reason why globular decanters filled with water and left incautiously exposed to the direct rays of the sun have been known to inflame various articles of furniture.

5. If a candle be placed in the focus *f*, the rays will go out parallel: if it be nearer the lens F G than the focus as at *x*, they will diverge in going out, and if it be placed farther from the lens, as at *z*, they will converge in going out of the glass, and meet in a point, which will be more or less distant from the lens, as the candle

is nearer to, or farther from its focus, and where the rays meet there will be an inverted image of the candle.

Experiment.—These facts may be shewn by taking the image of a lighted candle on a sheet of paper, by means of a common reading glass.

6. The image will be as much larger or less than the object, as its distance from the glass is greater or less than the distance of the object.

7. The *camera obscura* consists of a double convex glass so adapted as to fit to a hole in the shutter of a darkened chamber: behind this is fixed, at a proper distance, a sheet of paper, on which a picture of the external objects will be painted.

8. In a *portable camera obscura*, the lens is fixed in a box, and by means of a mirror placed at a proper angle, the picture is reflected upon oiled paper, on which the artist sketches his draught.

9. The *magic lantern* depends likewise on the double convex lens, which is fitted to a hole in a dark lantern, and little pictures painted in transparent colours on slips of glass are passed successively between the lens and the candle in the lantern, which pictures are painted on the wall of the room or a sheet, &c. that is placed to receive them. The figures must be inverted in the lantern if they are to be upright on the wall.

10. The phantasmagoria is like the magic lantern, only instead of painting the figures on transparent glass, all the glass is opaque except the figure only, which being painted in transparent colours, the light shines through it, and no light can fall upon the screen but what passes through the figure. The screen is very thin silk placed between the spectators and lantern, and by moving the lantern backwards or forwards the figures seem to recede or approach.

11. The multiplying-glass is on the principle of the plano-convex lens, but instead of a convex side, it is cut into several distinct surfaces, so that instead of seeing one object through it, we see as many objects as the glass has plane surfaces.

QUESTIONS FOR EXAMINATION.

1. What effect have parallel rays that fall on a plano-convex lens?

2. What is the effect of parallel rays falling on a double convex lens?

Give an illustration of these facts.

3. Where are the rays of the sun, that pass through a convex lens, collected, and how is the heat estimated?

4. What are burning glasses, and what effect have they produced by being exposed incautiously to the sun?

5. What effect will be produced by placing a candle in the focus of a convex lens, or nearer to, or farther from the lens than the focus?

What experiment shews this?

6. What will be the proportions between the object and image?

7. What is the principle of the camera obscura?

8. What is the construction of a portable camera obscura?

9. What is the principle of the magic lantern?

10. How is the phantasmagoria constructed?

11. What is the principle of the multiplying-glass?

LESSON THE FOURTH.

MICROSCOPES.

1. Microscopes are instruments for viewing small objects, and formed upon this principle, that they apparently magnify objects by enabling us to see them nearer, without affecting the distinctness of vision.

Experiment.—The eye brought close to a pin-hole in a sheet of brown paper, will, at the distance of two or three inches, see objects, as letters in a book, apparently magnified, though without the intervention of the paper the letters would at that distance be wholly illegible.

2. There are three kinds of microscopes, the *single*, the *compound*, and the *solar*; the two former depend wholly on refraction, the latter on reflection as well as refraction.

3. The *single* microscope is a small convex glass, having the object placed in its focus, and the eye at an equal distance on the other side of the glass.

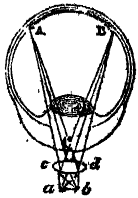


Fig. 3.

Explanation.—If the object be placed at $a\ b$, fig. 3, the rays from every point of it will, upon going out of the glass $c\ d$, be parallel, but the eye being also a convex lens they will be converged and brought to a focus on the retina where the picture is formed, but in an inverted position.

4. The magnifying power of this microscope is found by dividing six inches, the distance at which an object can be seen distinctly with the bare eye, by the focal distance; and the quotient will show how much the lens magnifies the diameter of the object.

Examples.—If the focal distance of the lens be half an inch, or a quarter of an inch, or one-tenth of an inch, then the diameter of the object will be magnified 12 times, or 24 times, or 60 times; and the area of the object will be magnified 144 times, or 576 times, or 3600 times.

5. The compound microscope consists of two lenses, viz. an object-glass, which is small and next the object; and an eye-glass, which is larger. In this instrument the distance of the object from the object-glass is somewhat greater than the focal length.

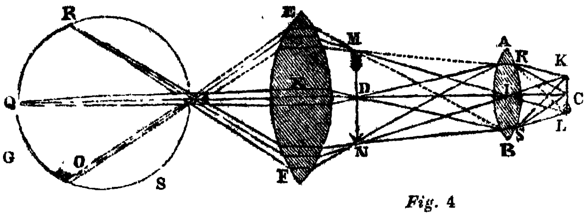


Fig. 4

Explanation.—Suppose R Q S, fig. 4, to be the eye, and K L the object placed a little beyond the focus of the lens A B, then the image of the object will be formed at M N, which will be inverted, but the rays of the image flowing through the eye-glass E F, will cross again; an erect image of the object will be formed on the eye, and the object will be seen inverted.

To enlarge the field of vision another and broader lens is often put between the object-glass A B and image M N.

6. The magnifying power of the compound microscope is in proportion as the image is larger than the object, and also according as we are able to view it at a less distance.

Example.—If the image M N be five times larger than the object K L, and by means of the eye-glass we can view it six times nearer than we could by the naked eye, then the instrument will magnify the diameter of the object $5 \times 6 = 30$ times, and the surface 30×30, or 900 times.

7. The solar microscope consists also of two convex lenses enclosed at their proper distances in a brass tube, which is to be fixed in the window shutter of a darkened room. The object is placed between the lenses, and the sun's rays passing through the object-glass, strongly illuminates the object, from which they pass through the second lens and form an inverted image of the object on the opposite wall. A mirror or looking-glass is used to throw the sun's rays still stronger on the object.

8. Telescopes answer the same end with respect to large and very remote bodies, that microscopes do with regard to small and near objects.

9. The astronomical telescope consists of two convex lenses in a tube whose distance from each other is equal to the sum of their principal foci: that lens which is towards the object is called the object-glass, and that next the eye is called the eye-glass. See fig. 4, p. 267.

10. Remote objects seen through an astronomical telescope appear inverted. But a telescope will not magnify unless the focal distance of the object-glass is greater than the focal distance of the eye-glass; therefore the object-glass should be less convex than the eye-glass.

Illustration.—It will be seen by what has been said, that in telescopes and compound microscopes, the image formed by one lens, viz. the object-glass, stands in place of a new object for the eye-glass. The operation may be seen by placing a screen of very fine gauze at the place of the image, which receives light enough to make the image visible in all directions, and yet transmits enough to fofm the subsequent image.

11. A telescope consisting of four convex lenses is often called a double telescope, and with this objects appear erect.

12. In reflecting telescopes a concave speculum or mirror is substituted for the object-glass, and the eye-glass is so placed as to magnify the image formed by the speculum.

13. In Dr. Herschel's telescope there is a concave reflector at the bottom of the tube, and the spectator stands with his back to the object, and looks in upon the reflector through the eye-glass.

QUESTIONS FOR EXAMINATION.

1. For what are miscroscopes used?
What experiment is given?
2. How many kinds of microscopes are there, and on what do they depend?
3. What is a single microscope?
Give the explanation.
4. How is the magnifying power of the single microscope estimated?
Give the examples.
5. Of what does the compound microscope consist?
Explain the construction.
6. How is the magnifying power of the compound microscope estimated?
Give the example.
7. Of what does the solar microscope consist, and how is the object to be placed?
8. For what are telescopes used?
9. Of what does the astronomical telescope consist?
10. How are remote objects seen by the astronomical telescope?
11. What is a double telescope?
12. What is the construction of a reflecting telescope?
13. What is the construction of Dr. Herschel's telescope?

LESSON THE FIFTH.

REFLECTION.

1. When rays of light strike against a surface, and are sent back from it, they are said to be reflected.

2. All objects whatever are rendered visible by the light which they reflect from the surface: even glass is distinguished by the rays which it reflects.

3. Bodies which transmit the rays of light are called transparent, those which do not transmit it are termed opaque.

4. Bodies with polished surfaces, which reflect the rays copiously, are called mirrors. These are chiefly made of metal, or glass, rendered opaque with an amalgam of tin and quicksilver.

5. Mirrors are made in various forms, viz. plane, convex, and concave. Common looking-glasses are plane mirrors.

6. The ray that comes from any luminous body and falls upon a reflecting surface is called the *incident* ray.

7. A ray of light striking perpendicularly upon a plane mirror is reflected back in the same direction.

8. Those rays which strike it obliquely are reflected back with the same degree of obliquity, but in an opposite direction, so that "*the angle of reflection is exactly equal to the angle of incidence.*"

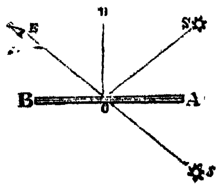


Fig. 5.

ILLUSTRATION.—If the ray *n*, fig. 5, fall upon the mirror A B in a perpendicular direction *n o*, it will be reflected back in the same line: but if a ray from the sun fall on the mirror in the direction S *o*, it will be reflected from *o* along the line *o* E so as to make the angle S *o* A equal to E *o* B, and the object S will appear, to an eye situated at E, to be at *s*, because *we see every thing in that line, in which the rays approach us last.*

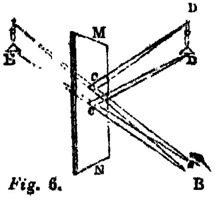


Fig. 6.

Again, suppose D D, fig. 6, to be a candle standing before a mirror M N; D C D C are the incident rays, C B C B the reflected: therefore to an eye situated at B the image of the candle will appear at B B, which is seen as far behind the mirror as the object is before it.

9. The images reflected by convex mirrors are less than the objects, and never of the true shape.

10. The images reflected by concave mirrors are magnified, and at a small distance behind the mirror, that is, when the objects are nearer the glass than the centre of concavity.

11. When the object is more remote than the centre of concavity, the image will be less than the object, inverted, and between the object and mirror.

12. When the object is in the centre of the mirror's concavity the image and object will coincide.

Experiment.—If a person stand before a large concave mirror, and beyond the centre of concavity, he will see an inverted image of himself in the air; and if he extend his hand towards the mirror, the hand of the image will come out and coincide with it; and if he extend it still farther, the hand of the image will pass by it. If he move his hand to one side, the hand of the image will move to the other.

QUESTIONS FOR EXAMINATION.

1. When are rays of light said to be reflected?
2. By what are objects rendered visible?
3. What are transparent and what opaque bodies?
4. What is meant by mirrors, and of what are they made?
5. How many kinds of mirrors are there?
6. What is meant by the incident ray?
7. How will a ray of light falling perpendicularly on a plane mirror be reflected?
8. How are rays reflected that fall on the mirror obliquely? Give the illustration.
9. What kind of images are reflected by convex mirrors?
10. What kind of images are reflected by concave mirrors, when the objects are nearer than the centre of concavity?
11. What kind will they be when the objects are more remote than the centre of concavity?
12. In what case will the object and image coincide?

Give an account of the experiment.

LESSON THE SIXTH.

OF THE EYE AND VISION.

1. The eye is of a globular form, and is composed of three coats, called the *sclerotica*, the *choroides*, and the *retina;* and three humours, denominated the aqueous, the crystalline, and the vitreous.

2. Objects are seen by means of their images being painted on the retina of the eye, in an inverted position, though they appear erect.

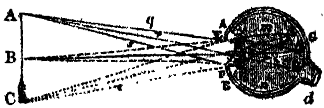


Fig. 7.

Explanation.—Fig. 7 represents a section of the eye, the three circles represent the coats; the outer one the sclerotica, but the front part of it A E F B is the cornea, that part which is always visible: the middle circle is the choroides, of which the forepart *x* is the iris, or the part which gives the character, as to colour, of the eye. The inner circle is the retina, on which the images of objects are painted. The aqueous humour fills up the front of the eye: the lens shaped part *y z* is the crystalline, and behind the crystalline is the vitreous humour: from the back of the eye proceeds the optic nerve *d*, which is an extension of the retina, and serves to convey to the mind sensations produced on that coat.

The object, in this case the arrow, A B C, sends out from all parts rays that fall on the cornea, and, by passing through the humours, they are refracted and converged to as many points on the retina, and there form a distinct and inverted picture of the object, *c b a*.

3. Dimness of sight may happen either by the eye being too flat or too convex, or in old age by the want of transparency in the humours.

4. To see an object distinctly it is necessary that every pencil of rays, as *q r s*, which comes from the object to the eye, should be converged to a point on the retina. If they converge to a point before they reach the retina, or not till they have got beyond it, the objects will be seen indistinctly and confused.

5. When the eye is too convex, the rays proceeding from an object are converged to a point before they reach the retina; to remedy this, concave spectacles are worn, which disperse the rays, and prevent them coming to a focus so soon as they otherwise would.

6. When the eye is too flat, the rays do not converge to a point so soon as they reach the retina, therefore convex spectacles are used to bring them to a focus sooner than they otherwise would.

7. When the crystalline humour loses its transparency the disorder is called a *cataract*, and the remedy applied is called *couching*, which is performed by thrusting a fine awl through the coats of the eye, and pushing the crystalline to the bottom of the eye, where it will remain, and its deficiency may be supplied with a convex lens.

8. When the defect of vision is in the optic nerve it is called a *gutta serena*, and the disorder is generally incurable.

9. The external parts of the eye, are the eye-brows, the eye-lids, and eye-lashes.

10. The eye-brows defend the eyes from too strong a light, and serve to turn away substances which might otherwise fall into the eye.

11. The eye-lids act as curtains, by covering and protecting the eyes during sleep: and in our waking hours they diffuse a fluid over the eye which renders it better adapted to transmit the rays of light.

12. The eye-lashes guard the organ from danger, and protect it from dust and insects floating or flying in the atmosphere.

QUESTIONS FOR EXAMINATION.

1. Of what parts does the eye consist?
2. How are objects seen?
Explain these facts.
3. From what causes does dimness of sight arise?
4. What is the requisite for seeing an object distinctly?
5. What defect is occasioned by an eye being too convex, and how is it remedied?

6. What defect is occasioned by too flat an eye, and how is it remedied?

7. What disorder is that which is occasioned by the loss of transparency in the crystalline humour, and how is it cured?

8. What is meant by a gutta serena?

9. What are the external parts of the eye?

10. Of what use are the eye-brows?

11. For what are the eye-lids designed?

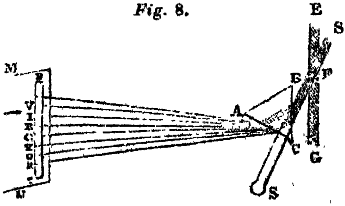
12. Of what advantage are the eye-lashes?

LESSON THE SEVENTH.

OF LIGHT AND COLOURS.

1. Light is not a simple body, but is compounded of seven different kinds, or colours, each of which in passing from one medium to another, suffers a different degree of refrangibility.

Fig. 8.



Explanation.—Let E G, fig. 8, represent a shutter of a room in which no light can enter but through the hole F. If a ray from the sun be admitted through the aperture F, it would form a circular image S, on any screen placed to receive it, but if a triangular piece of glass, A B C, called a prism, be made to intercept the ray, it will not proceed through the glass to *s*, but will be refracted to the screen or wall M N, and form an oblong image, P T, called a spectrum, of different colours, viz. red, orange, yellow, green, blue, indigo, violet. The red is the least refrangible, or the least bent out of the straight line S S; and the violet is the most refrangible.

2. If the whole spectrum be divided into 360 equal parts, the red will be found to occupy 45 of those parts; the orange 27; the yellow 48; the green 60; the blue 60; the indigo 40; and the violet 80.

3. As bodies reflect one or other of these colours, so they are denominated: those that reflect the red rays

are called red, and those that reflect the blue are called blue.

4. *White* is a compound of all the seven colours in the proportions mentioned in No. 2.

Experiment.—Let a circular board be painted with the seven colours in due proportion, that is, let it be divided into 360 parts, of which 45 are to be painted red; 27 orange; 48 yellow, &c., then turn the board with great velocity; this will produce the effect of mixing the colours, and the whole will appear of a sort of white. If the colours were more perfect the white would be so too.

5. *Black* is an entire deprivation of the colours, and when an object appears black, the light is completely absorbed.

6. The seven colours are reducible to three, the red, the blue, and the yellow.

7. The most remarkable instance of the natural separation of the primary colours of light is in the rainbow, which is formed by the refraction and reflection of the rays of the sun by drops of rain.

8. There are frequently two rainbows seen at the same time, the one strong and highly vivid, the other weak and ill-defined.

9. The vivid rainbow is occasioned by two refractions and one reflection: the ray of light is refracted in going into the drop, it is reflected to the other side of the drop, and refracted in coming out.

10. The faint bow is occasioned by two refractions and two reflections. To see a rainbow the sun must shine and be at a certain height in the heavens: and the spectator must stand between the sun and the shower.

11. In the vivid rainbow the violet colour will be uppermost and the red lowermost; and in the faint bow the colours will be reversed.

12. The rainbow will vary in height according to the height of the sun, for the higher the sun the lower the rainbow: and it is by the constant falling of rain in a shower that the image is preserved constant and perfect.

13. The colour of the sky depends on the vapours

in the atmosphere, which, as they are dense or rare, will reflect to the eye the more or less refrangible rays: hence in clear weather we have a blue sky, and when the atmosphere is loaded with vapours we have a dusky whiteness.

QUESTIONS FOR EXAMINATION.

1. Is light a simple body?
Can you explain the subject by the figure?
2. What are the proportions of the several colours?
3. How are bodies denominated with respect to colour?
4. What occasions a white?
How is it exhibited in the experiment?
5. How is black occasioned?
6. Are the seven colours reducible to a less number?
7. What is the most remarkable instance of the natural separation of colours?
8. Is there more than one rainbow seen at a time?
9. How is the vivid rainbow occasioned?
10. How is the faint rainbow occasioned?
11. How are the colours arranged in the two bows?
12. How does the rainbow vary in height?
13. On what does the colour of the sky depend?

ASTRONOMY.

ON THE SUN.

"Fair Sun, who with unchanging beam
Rising another and the same,
Dost from thy beamy car unfold
The glorious day,
Or hide it in thy setting ray."
Horace, translated by Francis.

"Great Source of Day! best image here below
Of thy Creator, ever pouring wide,
From world to world, the vital ocean round,
On nature write with every beam his praise."—*Thomson.*

THE sun has been justly styled the soul of the universe, as it not only produces all the necessaries of life, but has a particular influence in cheering the mind of man. He can never be satiated then, one would think, with the glorious scenes

which the eye discovers, when the radiant orb sheds its lustre abroad; nor can imagination ever cease to contemplate with pleasure, his wonderful use, and essential importance in the creation.

The rising of the sun is perhaps the most beautiful phenomenon in nature. How striking the scene when we first observe the fiery rays which he scatters among the clouds, as harbingers of his approach. As the illumination increases, the earth seems all in a glow; and we expect the glorious orb, long before he discovers himself above the horizon. We imagine every moment that we see him. At length he appears. His rays dart like lightning over the face of nature, and darkness vanishes at the sight. Man glories in his habitation, and beholds it embellished with renovated beauty. The lawn is refreshed by the coolness of the night, and the light of the morning displays its increasing verdure. The dew-bespangled flowers, that enamel its surface, glitter in the sunbeams, and like rubies and emeralds, dart their colours on the eye. The cheerful birds unite in choirs, and hail, in concert, the PARENT OF LIFE. At this enchanting moment not one is silent. All nature is enlivened by his presence, and gladdened by his gifts. Millions of glittering insects awake into existence, and flutter in his rays. The bleating flocks, and lowing herds, salute the welcome blessing. The hills, the valleys, and the woods resound with rural harmony. All that is vocal unites in the general choir; and all that has breath exults in the enlivening influence. In man, in particular, the assemblage of so many pleasing objects imparts a glowing sensation, that seems to penetrate the soul. Who, indeed, can withstand the rapture of this short interval of enchantment? Who can behold with indifference a scene, at once so magnificent, so beautiful, and so delightful?

A complete account of the nature and properties of this glorious orb would lead me into enquiries too extensive for the limits of this paper: into a view not only of the solar system, that is of our earth, and the other planets, which, with the comets, revolve at stated periods round the sun; all of which are fully detailed and set forth in the following lessons; but it would lead me to the contemplation also of all the visible nocturnal heavens, that is, of the fixed stars, which astronomers suppose to be so many suns, illuminating and pervading an infinity of other systems, throughout the immensity of space.

That radiant orb, with which, as a part of the planetary system to which our globe belongs, we are so intimately con-

nected, is defined, with respect to us, to be that great luminary which enlightens the world, and whose presence constitutes the day.

The figure of the sun is a spheriod higher under the equator than about the poles. His diameter is computed to be 880,000 miles. His solid bulk is 64 millions of times as big as the moon's, and a million of times bigger than the earth's. His distance from the earth, in round numbers, is about 95 millions of miles; a distance so prodigious, that a cannot ball, which is known to move at the rate of about eight miles in a minute, would be something more than twenty-two years in going from the earth to the sun. This account of the diameter, magnitude and distance of the sun, is derived from the determination of the most eminent astronomers in Europe, who were sent out to the most convenient parts of the earth, for the purpose of observing the transits of Venus over the sun, that happened in the years 1761 and 1769, and confirmed and corroborated by the eminent men who have succeeded them, and whose labours and discoveries carry more proximate dates.

The sun was generally considered by the ancients as a globe of pure fire; but from a number of maculæ or dark spots, which by means of a telescope, may be seen on different parts of his surface, it appears that this opinion was ill-founded. The spots consist in general of a nucleus or central part, which appears much darker than the rest, and seems to be surrounded by a mist or smoke; and they are so changeable in their situation and figure, as frequently to vary during the time of observation. Some of the largest of them, which are found to exceed the bulk of the whole earth, are often to be seen for three months together; and when they disappear, they have been supposed to be converted into faculæ, or luminous spots, which appear much brighter than the rest of the sun. About the time that the solar spots were first discovered by Galileo, forty or fifty of them might frequently be seen on the sun at a time; but at present we can seldom observe more than thirty; and there have been periods of seven or eight years in which none could be seen.

Various have been the opinions concerning the nature, origin, and situation of the spots on the sun. It has been imagined, that the maculæ are occasioned by smoke and opaque matter thrown out by volcanos or burning mountains of immense magnitude; and that when the eruption has nearly ended, and the smoke dissipated, the fierce flames

are exposed, and appear like faculæ or luminous spots. The sun by some astronomers has been imagined to be in a continual state of fusion, and they have thought that the spots which we observe, are only the eminences of large masses of opaque matter, which, by the irregular agitations of the fluid, sometimes swim upon the surface, and sometimes sink and disappear. Others have supposed them to be occasioned by a number of planets circulating round the sun at a small distance from his surface. The results of other observations, are that the solar maculæ are cavities in the body of the sun; that the mucleus, as the middle or dark part has been usually called, is the bottom of the excavation; and that the umbra, or shady zone, usually surrounding it, is the shelving sides of the cavity. The reality of these immense excavations in the body of the sun, appears not only to be thought to be very satisfactorily ascertained by some philosophers, but a method of measuring the depth of them has likewise been pointed out. Dr. Alexander Wilson,* a celebrated professor of astronomy in the University of Glasgow, toward the close of the last century, who first advanced the opinion, that there are hollows in the surface of this luminary, offers upon his supposition some queries and conjectures concerning the sun himself. He asks whether it is not reasonable to think, that the vast body of the sun is made up of two kinds of matter very different in their qualities; that by far the greatest part is solid and dark; and that this dark globe is encompassed with a thin covering of that resplendent substance, from which the sun would seem to derive the whole of his vivifying heat and energy? Dr. Herschel supposes, says a modern writer, "that the sun is an opaque body, surrounded by an atmosphere of a phosphoric nature, composed of various transparent and elastic fluids, by the decomposition of which light is produced, and lucid appearances formed of different degrees of intensity." According to his theory, which is both rational and plausible, "maculæ are those parts of his surface which happen to be free from luminous decompositions, or in other words, which are but slightly, if at all covered by the shining matter, and are for that reason exposed to our view." "Faculæ, on this hypothesis, are those parts of the solar atmosphere which are brighter, and in general more elevated than the rest. These Dr. Herschel supposes to be "more copious mixtures of such fluids as decompose each

* An ample detail of the ingenious and learned observations of this celebrated writer upon this subject: the student will find in the 64th volume of the Philosophical Transactions.

other," or they may be called "larger collections of the luminous fluids which form the solar atmosphere, according to the quantity, brightness, and depth of which, the faculæ differ in magnitude and intensity."

The motion of the maculæ is from east to west, and as they are observed to move quicker when they are near the central regions than when they are near the limb, it follows that the sun must be a spherical body, and that he revolves on his axis in a contrary direction, or from west to east.

Besides the solar spots, the zodiacal light is a singular phenomenon which accompanies the sun, and is usually attributed to his atmosphere. It begins to appear a little before sunrise, and seems at first like a faint whitish zone of light, resembling the milky way, with its borders ill-terminated, and scarcely to be distinguished from the twilight, which is seen commencing near the horizon. It is then but little elevated, and its figure nearly agrees with that of a flat lenticular spheriod, seen in profile. As it rises above the horizon, it becomes brighter and larger to a certain point, after which the approach of day renders it gradually less apparent, till it becomes quite invisible.

From this account of the sun, and the principal phenomena that he exhibits, the next and most obvious enquiry is into his pervading energy and essential importance in the creation, and particularly to our globe. But nothing can equal what Thomson has said upon this subject in his beautiful Hymn to the Sun. In conclusion, therefore, I refer the student to this, not only as a poetical illustration, but as the noblest account that has ever been given of the dignity, the use, and the beauty of this resplendent orb.

LESSON THE FIRST.

SOLAR SYSTEM.

1. Astronomy is the science which treats of the heavenly bodies, and explains their forms, distances and appearances.

2. Upon an accurate knowledge of astronomy, depend the sciences of geography, chronology and navigation: for by its assistance man traverses the seas, penetrates into foreign countries, becomes acquainted

with various parts of the earth, and ascertains with precision the dates of events that are past.

3. The heavenly bodies are the sun, the planets, with their satellites or moons, the comets which belong to our system, called the "Solar System," and the fixed stars which are suns to other systems.

4. The solar system consists of the sun in the centre of seven planets, viz. Mercury, Venus, the Earth, Mars, Jupiter, Saturn, and the Herschel, or Georgium Sidus:* to these belong thirteen satellites, and between Mars and Jupiter are four smaller planetary bodies discovered during the last ten years. To these are to be added comets.

5. The paths in which the planets and comets move round the sun are called their orbits.

6. Mercury and Venus are called inferior planets because they are nearer the sun than the earth: their orbits are included in that of the earth, being frequently seen between the sun and earth.

7. Mars, Jupiter, Saturn, and the Herschel, are denominated superior planets, being situated at greater distances from the sun than that of the earth: that is, the orbit of the earth is included within those of the superior planets.

8. Mercury, the planet nearest the sun, travels round that luminary in about 87 of our days, at the distance of 37 millions of miles. It is the smallest of the planets, his diameter being about 3000 miles in length; and from its situation it must enjoy seven times more light and heat from the sun than the earth.

9. Venus, the brightest of all the planets, revolves about the sun at the distance of 68 millions of miles, and completes her revolution in 224 of our days. Her diameter is about 7700 miles in length, and she enjoys

* The discoveries of Dr. Herschel form a new æra in astronomy. This new primary planet was called by him the Georgium Sidus, or Georgian, a name by which it is distinguished in the Nautical Almanac: but named the Herschel, by foreign astronomers, in honour of himself as the discoverer. Our author retains that designation, in my opinion very properly.

twice as much more light and heat from the sun than the earth.

10. Mercury and Venus, when viewed through a good telescope, shew phases like the moon: they are never seen in those parts of the heavens that are opposite to the sun, and from their appearing to be always near the sun, they are called attendants upon that body.

11. Venus and Mercury occasionally appear to pass over the sun's surface. These are called the *transits* of Venus and Mercury.

12. By the transits of Venus in the years 1761 and 1769, the sun's distance from the earth was first accurately ascertained to be between 95 and 96 millions of miles.

13. When Venus appears east of the sun, that is, when she sets after the sun sets, she is called an "evening star;" and when she is west of the sun, or when she rises before the sun, she is called a "morning star."

QUESTIONS FOR EXAMINATION.

1. What is astronomy?
2. What sciences depend on astronomy?
3. Which are denominated the heavenly bodies?
4. Of what does the solar system consist?
5. What are the orbits of the planets?
6. Which are the inferior planets, and why are they so called?
7. Which are the superior planets, and why are they so called?
8. What are the facts relating to Mercury?
9. What is said of Venus?
10. What appearances do Venus and Mercury exhibit when viewed through a telescope?
11. What is meant by the transits of Venus and Mercury?
12. To what purpose has the transit of Venus been applied?
13. When is Venus called an evening, and when a morning star?

LESSON THE SECOND.

OF THE EARTH.

1. The earth is a round or spherical body almost 8,000 miles in diameter; it moves round the sun in about 365¼ days.

ILLUSTRATION.—The spherical form of the earth is proved

from its always casting a round shadow on the moon during an eclipse:—from its having been actually sailed round by different navigators:—from our seeing farther the higher we stand:—and from our seeing the masts of ships on the sea, while the hull is hidden by the convexity of the water.

2. The earth turns on its axis in about 24 hours, which is called the diurnal motion, and which is the cause of the perpetual changes of day and night. It being day to that half of the earth which is opposite the sun, and night to the inhabitants of the other half.

3. The motion of the earth is from west to east, which gives the appearance of the sun's motion from east to west, for when any part of the earth, London for instance, turns into the sun's light, the appearance is the same as if the sun, by its motion, in a contrary direction, came into sight of the earth.

4. The different seasons are occasioned by the annual revolution of the earth round the sun, which causes the sun to appear to rise and set every day at different points of the horizon; and to be higher in the heavens in some parts of the year than at others.

5. According as the sun is higher in the heavens, and longer above the horizon, the days are hotter.

6. When it is summer to the northern parts of the earth, it is winter in the southern.

7. The *sensible horizon* is that apparent circle which, on an extensive plane, or on the surface of the ocean, seems to bound the sphere of vision.

8. The *rational horizon* divides the heavens into two equal parts or hemispheres,—the visible, which is above, and the invisible, which is below it.

9. The sun, moon, planets, and fixed stars, appear to revolve about the earth in 24 hours.

10. The meridian divides the time of the course of the celestial bodies above the horizon into two equal parts, and when the sun is at the meridian it is mid-day.

11. When we look directly to the north, we have the south at our back; the west on the left hand; the east on the right: the point directly over our heads is called the zenith, and the nadir is under our feet.

12. The equator or equinoctial is that great circle which is supposed to divide the globe into two equal parts, the one north and the other south.

13. The ecliptic is the sun's apparent annual path: the angle which it makes with the equator is called the obliquity of the ecliptic, and the points where it intersects the equator are called the equinoctial points.

14. The zodiac is a broad portion of the heavens, following the direction of the ecliptic, and extending about eight degrees on each side of it.

15. The tropics are the circles parallel to the equator, that towards the north is called the tropic of Cancer, and that towards the south the tropic of Capricorn.

16. The earth is called a parallel, or right, or oblique sphere, according to the position of the inhabitants.

17. To the people who live at the poles, if there be any, the earth is reckoned a *parallel sphere*, because there the equator is parallel with the horizon. The poles are in the zenith and nadir: and there the people have but one day and one night in the year, each being six months.

18. To the people who live at the equator the earth is a *right sphere*, because there the equator is at right angles to the horizon; the poles will lie in the horizon, and the zenith and nadir will be in the horizon.

19. To those who live in any other part of the earth except the poles and the equator, the earth is an *oblique sphere*, because to them the equator cuts the horizon obliquely.

20. To the inhabitants of an oblique sphere, those who live beyond the tropics never have the sun in their zenith: but to those under the tropics he is vertical once, and to those between the tropics and the equator twice every year.

QUESTIONS FOR EXAMINATION.

1. What is the earth, and in how long does it move round the sun?

Give the illustration.

2. What do you mean by the diurnal motion of the earth?

3. Which way does the earth turn, and what appearance does it occasion?

4. By what are the different seasons occasioned?
5. What are the causes of the hot days?
6. When it is summer in the northern parts of the globe, what is it in the southern?
7. What is the sensible horizon?
8. What is the rational horizon?
9. How do the sun and planets appear to move?
10. What is the meridian?
11. How do you find the north, and south, &c?
12. What is the equator?
13. What is the ecliptic?
14. What is the zodiac?
15. What are the tropics?
16. How is the earth called with respect to the position of the inhabitants?
17. To whom is the earth a parallel sphere?
18. To whom is the earth a right sphere?
19. To whom is the earth an oblique sphere?
20. How does the sun affect those who live in an oblique sphere?

LESSON THE THIRD.

OF MARS, JUPITER, SATURN, AND THE HERSCHEL.

1. The planet Mars is at the distance of 144 millions of miles from the sun, and the length of his year is equal to 687 of our days. His day is a little longer than ours, being 24 hours 39 minutes.

2. The diameter of Mars is almost 4,200 miles in length; and he enjoys only about half as much with respect to light and heat from the sun that we enjoy.

3. Jupiter is the largest of all the planets, his diameter being 90,000 miles in length, and he is 490 millions of miles distance from the sun, and enjoys only a twenty-fifth part of the light and heat that we experience.

4. Jupiter's year is equal to about twelve of our years, and his day and night are equal to ten of our hours.

5. Jupiter has four satellites, which are subject to be eclipsed like our moon, and from these eclipses has been ascertained the velocity of light.

6. Saturn is 900 millions of miles from the sun: his diameter is 80,000 miles in length, and his year is equal to thirty of ours.

7. Saturn enjoys ninety times less heat and light from the sun than we have; yet his light is equal to what would be produced by 500 of our moons when at the full.

8. Saturn has seven satellites or moons, and he is encompassed with two broad rings, which are supposed to be of considerable importance in reflecting the sun's light to the planet. His day is not half the length of ours.

9. The Herschel planet was discovered by Dr. Herschel, from whom it takes its name, in the year 1781; it is too small to be discerned by the naked eye.

10. The diameter of the Herschel is 35,000 miles long, and he is 1,800 millions of miles from the sun, around which he performs his journey in eighty-two of our years.

11. The light of the sun at the Herschel is equal to nearly as much as 250 of our moons at the full would supply.

12. The Herschel has six moons to afford him light in the absence of the sun.

13. Comets, like the planets, revolve about the sun, in very eccentric or long orbits, so that at some periods they are beyond our observations, and at others they are much nearer the sun than Mercury, the nearest of the planets.

14. Comets are usually accompanied with tails of great length and extent, appearing as a faint light always directed towards a point nearly opposite the sun.

15. A very brilliant comet was distinctly seen by the naked eye, for several weeks in the autumn of the year 1807, and another was observed for some time in 1811

QUESTIONS FOR EXAMINATION.

1. What facts are mentioned with respect to Mars?

2. What is the length of the diameter of Mars, and what proportion of light and heat does he enjoy?

3. What facts are mentioned with respect to Jupiter?
4. What is the length of Jupiter's year and day?
5. How many satellites are there belonging to Jupiter, and to what have their eclipses been applied?
6. What are the facts mentioned with respect to Saturn?
7. What proportion of light and heat does Saturn enjoy?
8. How many satellites has Saturn, and of what use are his rings?
9. When and by whom was the Herschel planet discovered?
10. What facts are mentioned concerning this planet?
11. What proportion of light does he enjoy?
12. How many moons has the Herschel?
13. What is said of comets?
14. With what are they accompanied?
15. When did the last comets appear?

LESSON THE FOURTH.

OF THE MOON AND OTHER SATELLITES.

1. The diameter of the moon is 2,200 miles in length, and she revolves about the earth at the distance of 240,000 miles from it.

2. The moon shines by a light borrowed from the sun; her year is of the same length as ours: but her day and night are together equal to about 29½ of ours.

3. When the moon is in a line between the earth and sun it is invisible, and is said to be in conjunction: it is then new moon, or change, but we call it new moon, the first time it is visible after change, that is, the second day after change.

4. The moon is invisible at change, because her enlightened half is entirely turned away from the earth; and as she advances in her orbit we get, by degrees, a sight of her enlightened half.

5. When the earth is directly between the sun and moon, they are said to be in opposition, and the moon is said to be full, because we see all her enlightened half.

6. She then declines and shews less and less of her enlightened surface till change, when it is again lost to the earth.

7. The moon is thought to be inhabited, because it bears a general analogy to the earth: and the earth answers the purpose of a moon to her, only appearing thirteen times larger than our full moon appears, and is subject likewise to the same changes of horned, gibbous, full, &c.

8. Before the full, the horns of the moon are turned to the west, and after the full they are turned to the east.

9. When any heavenly body is obscured or darkened by the shadow of another falling upon it, or by the interposition of any body between it and the sun, it is said to be eclipsed.

10. The earth being an opaque body, enlightened by the sun, will cast a shadow towards that side which is farthest from the sun.

11. The moon revolves about the earth near enough to pass through the shadow projected by the earth.

12. An eclipse of the moon takes place when the sun, the earth, and the moon, are in a straight line, and it is occasioned by the moon's passing through the shadow projected by the earth.

13. An eclipse of the sun happens when the moon is in an exact line between the sun and earth, that is, at the time of *change* or new moon, and it is occasioned by the moon's intercepting the light of the sun.

14. The moon rises on an average three quarters of an hour later on one day than it did the preceding; but about the time of full moon in September, the difference of time for several evenings together is not more than from fifteen to twenty minutes each evening: this is called the harvest moon, from the advantages which its light confers at that season.

15. In the polar circles the full moon never rises in summer when she is not wanted, nor sets in winter when her light is so much required.

16. Jupiter has four satellites, which were among the very earliest discoveries of the telescope by Galileo, the inventor of that instrument, in the year 1610.

17. Saturn has seven satellites, two of which, viz.

those nearest the planet, were discovered by Dr. Herschel in the year 1789.

18. The Herschel planet has six satellites, all discovered by Dr. Herschel, after whom, as the discoverer, the planet is named.

19. The four smaller planetary bodies discovered during the present century have been named, "The Ceres Ferdinandea," discovered by M. Piazzi; "The Pallas," discovered by Dr. Olbers; "The Juno," discovered by M. Harding; and "The Vesta," discovered by Dr. Olbers.*

20. The largest of these is the Pallas, being rather more than 2,200 miles in diameter: it revolves about the sun in four years and eight months, at the distance of 288 millions of miles.

21. Its orbit and those of the other three are all between Mars and Jupiter.

QUESTIONS FOR EXAMINATION.

1. What is the length of the diameter of the moon, and at what distance is it from the earth?

2. How does the moon shine, and what is the length of her year and of her day?

3. What is meant by new moon?

4. Why is the moon invisible at change?

5. When is it full moon?

6. What happens after the moon is full?

7. Is the moon supposed to be inhabited?

8. How are the horns of the moon situated before and after it is full?

9. What is meant by a body being eclipsed?

10. What is the consequence of the earth being enlightened by the sun?

11. Can the moon pass through the shadow projected by the earth?

12. When does an eclipse of the moon happen?

13. When does an eclipse of the sun happen?

14. What is meant by the harvest moon?

* The Ceres was discovered 1st. January, .. 1801.
— Pallas ———— 20th. March, .. 1802.
— Juno ———— 1st. September, 1804.
— Vesta ———— early in ...... 1807.

15. In what place and at what time does the moon when at the full never rise nor set?

16. How many satellites has Jupiter, and by whom were they discovered?

17. How many satellites has Saturn?

18. How many satellites has the Herschel?

19. What are the names of the smaller and lately discovered planetary bodies?

20. Which is the largest of them?

21. How are their orbits situated?

LESSON THE FIFTH.

OF THE SUN AND FIXED STARS.

1. The sun, though appearing to us only as a circular disc, is of a spherical form, having a diameter equal to 880 thousand miles in length.

2. The sun is situated at the centre of the system of the planets, over which it perpetually exerts the most important influence: it affords them heat and light, more or less in proportion to their distances from it: by the gravitating power of the sun also the planets are kept in their orbits.

3. The sun, like the fixed stars, shines with its own unborrowed light: and may be considered as a fixed star.

4. The sun revolves on its axis in twenty-five days ten hours, in a direction from west to east, the time and direction are ascertained by the spots which are usually to be seen on his surface.

5. The quantity of matter in the sun is to that contained in Jupiter, as 1,100 to 1.

6. The sun's diameter is equal to 100 diameters of the earth, and therefore its magnitude is a million of times larger than the earth: but its density is nearly four times less than that of the earth, so that the quantity of matter in the sun to that in the earth is as 250,000 to 1.

7. The fixed stars are at immense distances from the earth, shine by their own light, and are doubtless suns

to other systems of planets. They are called fixed, because they never appear to change their places with respect to one another like the planets.

8. The light of the stars appears to the naked eye to be white, being too faint to excite the idea of any particular colour, but if the light be highly concentrated by immense specula, it appears of different colours.

9. Not more than 1,000 stars are visible at once, and from one place by the naked eye.

10. The stars, on account of their apparently various magnitudes, have been distributed into classes or orders: those which appear largest are called stars of the first magnitude: the next to them in lustre, stars of the second magnitude, and so on to the sixth magnitude, which are the smallest that are visible to the naked eye. The others are called telescopic stars.

11. The stars are arranged in constellations, supposed to represent certain figures of animals, &c. which divisions serve to distinguish them from one another, so that any star may, by the assistance of the terrestrial globe, be readily found out.

12. There are about seventy constellations, and the principal stars are marked by the letters of the Greek alphabet. The stars not included in any constellation, are called unformed stars.

13. Particular names are likewise given to some small collections of stars, and also to remarkable stars of the first magnitude: thus the cluster of small stars in the neck of the bull is called the Pleiades: the five stars in the bull's face are denominated the Hyades: a brilliant star in the Lion's heart is called Leo, and a large star between the knees of Bootes is called Arcturus.

14. The luminous part of the heavens called the Milky Way, consists of fixed stars too small to be seen by the naked eye.

15. There are spots in the heavens called *Nebulæ*, some of which consist of clusters of telescopic stars, others appear as luminous spots of different forms.

16. Each nebula is thought to be composed of a

number of suns, and each sun is probably destined to give light to a system of worlds.

17. There are also *nebulous* stars, that is stars surrounded with a faint luminous atmosphere.

QUESTIONS FOR EXAMINATION.

1. How is the sun described?
2. How is it situated, and how is its influence exerted?
3. With what kind of light does it shine?
4. Does it revolve on its axis, and how was that ascertained?
5. What is the quantity of matter in the sun compared with that of Jupiter?
6. What is the size of the sun compared with the earth?
7. What are fixed stars?
8. What colour is the light from the fixed stars?
9. How many stars are visible at the same time and place?
10. How are the stars distributed?
11. How are they arranged?
12. How many constellations are there, and how are the single stars marked?
13. Are names given to any small collections of stars?
14. What is the Milky Way?
15. What are the nebulæ?
16. What is each nebula?
17. What are nebulous stars?

LESSON THE SIXTH.

OF THE TIDES.

1. The tides are occasioned by the ebbing and flowing of the sea, which are caused by the attraction of the sun and moon, but chiefly by the latter.

2. The attraction causes the waters to assume a spheroidal figure, the longest axis being in the direction of the moon.

3. The highest tide is at that place which is just under the moon, not indeed when the moon is on the meridian, but some little time after, because the force of attraction continues to act after it has passed the meridian.

4 The spheroidal figure of the waters keeps pace with the moon in its journey round the earth, which by its diurnal rotation upon its axis, presents each part of its surface to the action of the moon.

5 There are two tides in every place, occasioned by the attraction of the moon, in about 24 hours and 53 minutes.

ILLUSTRATION.—If the moon were stationary there would be two tides in 24 hours; but the moon proceeding 13 degrees in her orbit from west to east, the earth must make more than one revolution on its axis before the same place is in conjunction with the moon, and therefore the two tides take place in 24 hours and 50 minutes. There are two tides, because the action of the moon produces a tide in the place over which it passes, and also in the opposite surface at the same time.

6. The moon, from the eliptic form of her orbit, is sometimes nearer the earth than at others; when she is nearest, the attraction is the strongest, and the tides the highest: hence the reason of high and low tides.

7. The force of the sun, in raising the tides, is to that of the moon only as 1 to 5; when the sun and moon both act in the same direction at the time of full moon, the tides will be raised as 5 + 1 or 6, which is the cause of "spring-tides," but when they act in opposite directions, as in the quarters, they will be raised as 5 — 1 or 4, which is the cause of "neap tides."

8. The highest tides happen a little before the vernal, and a little after the autumnal equinoxes.

9. In open seas the tides rise but to very small heights in proportion to what they do in wide mouthed rivers, opening in the direction of the stream of the tide; for in channels growing gradually narrower, the water is accumulated by the opposition of the contracting bank.

10. The irregularity of the tides is occasioned by their passage through narrow channels, and by their striking against capes and head-lands, which cause the tides to happen at different hours according to the situation of the place.

11. In general the greatest height of the water in

open seas, happen about an hour after the moon has left the meridian of the place.

12. In the German Ocean the highest tide is three hours after the moon has passed the meridian, and it is twelve hours in coming from thence to London Bridge.

13. There are no tides in lakes, because they are so small, that when the moon is vertical over them she attracts every part of them alike.

14. The tides in the Mediterranean and Baltic seas are but trifling, because the inlets by which they communicate with the ocean are so narrow, that they cannot, in a short time, receive or discharge enough to raise or sink their surface very much.

QUESTIONS FOR EXAMINATION.

1. How are the tides occasioned?
2. What does the attraction produce?
3. Where and when is the highest tide?
4. How is each part of the earth presented to the moon's attractive influence?
5. How often are tides occasioned?
Give the illustration.
6. When are the tides the highest?
7. Explain the cause of spring and neap tides.
8. When do the highest tides happen?
9. Do the tides rise higher, or not so high in the open seas, as in rivers connected with them?
10. What occasions the irregularity of the tides?
11. At what time does the highest tide happen in open seas?
12. When is it highest in the German Ocean?
13. Why are there no tides in lakes?
14. Why are the tides in the Baltic and Mediterranean but trifling?

ELECTRICITY.

THE FRANKLINIAN THEORY.

"Electricity possesses much of what is admirably adapted to discipline the mind."—*Morgan.*

ELECTRICITY is a term used to denote the operations of a very subtile fluid, in most cases invisible; but which sometimes becomes the object of our senses, proving itself to be one of the principal agents employed in producing the phenomena of nature.

The attractive power which amber and other electric bodies acquire by friction, was long known to philosophers; and it may be remarked, although perhaps almost unnecessary, that this branch of science derives its name from *electron*, the Greek word for amber. The other electric properties were slowly discovered. Mr. Boyle was the first who had a glimpse of the electric light; as he remarked, after rubbing some diamonds in order to give them the power of attraction, that they afforded light in the dark.

As the student will perceive by the fourth proposition in the following lessons, it was formerly conjectured that there were two kinds of electricity; but Dr. Franklin, whose theory is now generally adopted, rejected this idea. He supposes that the electric matter is every where the same, and that all bodies contain a certain portion of this matter. Glass, and those substances, however, which are denominated electrics, he supposes contain a large portion of the matter, but are not to be penetrated by it; and those substances, on the contrary, which are called non-electrics or conductors, he regards as permeable, or capable of being penetrated by it.

When any body contains a superfluous quantity of the electric fluid, it is then, according to Franklin's theory, electrified *positive*, or *plus;* when it contains less than its proper share, it is said to be *negative* or electrified *minus*, that is, some of its electricity is taken from it. That electricity, therefore, which was before called *vitreous*, Dr. Franklin calls positive electricity; and that which was termed the resinous, he considers as negative electricity. If, therefore, a rough and smooth body are rubbed together, the smooth body in general will have the positive electricity, and the rough the

negative. Thus, in the ordinary operation of the electrical machine, the cylinder is positively electrified or *plus*, and the rubber negatively or *minus;* and the redundancy of the positive electricity is sent from the cylinder to the prime conductor. This, however, is supposing the chain, which communicates with the earth, to be at the same time in contact with the rubber; for as the earth is the grand repository of the electrical matter, if the chain is removed, and put over the prime conductor, these effects will be reversed, and the prime conductor will then be negatively electrified, or *minus*, and the rubber will be *plus* or positive.

Electricity accelerates the evaporation of liquors, and the perspiration of animals. There is reason also to apprehend that it is not without effect upon the vegetable creation, as from some experiments we are led to conclude, that plants which have been electrified, vegetate earlier and more vigorously than those which have not been subjected to its influence.

Electricity is, indeed, a most powerful agent in nature, and we are probably not yet acquainted with all its effects. It is however, in the atmospherical phenomena, that these effects are the most apparent and tremendous. It is to Dr. Franklin that we are indebted for the amazing discovery, that the cause which produces THUNDER and LIGHTNING is precisely the same with that which produces the ordinary phenomena of electricity.

This truly eminent philosopher was led to the discovery by comparing the effects of lightning and those produced by an electrifying machine, and by reflecting that if two gun-barrels when electrified will strike at two inches with a loud report, what must be the effect of ten thousand acres of electrified cloud. After much thought upon the subject, he determined to try whether it was not possible to bring the lightning down from the heavens. A thought at once daring and sublime! With this view he constructed a kite, like those which are used by school-boys, but of a larger size and stronger materials. A pointed wire was fixed upon the kite, in order to attract the electrical matter. The first favourable opportunity he was impatient to try his experiment, and he sent his kite up into a thunder cloud. The experiment succeeded beyond his hope. The wire in the kite attracted the electricity from the cloud; it descended along the hempen string, and was received by an iron key attached to the extremity of the hempen string: that part which he held in his hand being of silk, in order that the electric fluid might stop when it reached the key. At this key he charged phials, with which

phials thus charged he kindled spirits, and performed all the common electrical experiments.

Thus it is evident that the cause of those terrible convulsions of nature, which in warm climates especially, are attended with such tremendous effects, is no other than a superfluous mass of electrical matter collected in these immense watery conductors, the clouds; and that this matter is discharged when an electrical cloud meets with another which is less powerfully charged, or when it is brought sufficiently near the earth to be within the sphere of the electrical attraction. This fact may be proved at almost any time, but particularly in a sultry summer's evening, by repeating Dr. Franklin's experiment with the kite.

Thunder storms in this country are seldom attended with fatal effects, yet it is desirable to be made aware of their approach. They are generally observed to happen when there is little or no wind, and are preceded by one dense cloud or more, increasing very rapidly in size, and rising into the higher regions of the air. The lower surface is black, and nearly level, the upper parts are arched and well defined; sometimes many of them appear piled one upon another, all arched in the same manner. At the time this cloud rises, the air is generally full of separate clouds, motionless, and of whimsical shapes. These gradually are drawn towards the thunder cloud, and when they come near it their limbs mutually stretch towards each other, and then coalesce. Sometimes, however, the thunder cloud swells and enlarges without the addition of these clouds, from its attracting the vapours of the atmosphere, wherever it passes. When the thunder cloud is grown to a great size, the lower surface becomes rugged, parts being detached towards the earth, but still connected with the rest. About this time also it seems to sink lower, and a number of small clouds are driven about under it, in very uncertain directions. It is while these clouds are most agitated that the rain or hail falls in the greatest abundance.

While the thunder cloud is swelling, and extending its branches over a large tract of country, the lightning is seen to dart from one part of it to another, and often to illuminate its whole mass. When the cloud has acquired sufficient extent, the lightning strikes between it and the earth in two opposite places. As the lightning continues, the cloud grows thinner, till at length it breaks in different places, and displays a clear sky.

The clouds, however, are sometimes negatively electrified with respect to the earth, and in this case the lightning is

supposed to proceed from the earth to the cloud; but the mischievous effects are the same, and in fact, there is reason to think that this is a rare case.

During a thunder storm the safest place is in the cellar; for when a person is below the surface of the earth, the lightning must strike it before it can reach him, and its force will therefore be probably expended on it. When it is not possible to retreat to the cellar, the best situation is in the middle of a room, not under a metal chandelier, or any other conducting surface; and it is adviseable to sit on one chair and to lay the feet up upon another: persons in fields should prefer the open parts to any shelter under the trees, &c. The distance of a thunder cloud, and consequently the degree of danger, is not, however, difficult to be estimated. As light travels at the rate of 72,420 leagues in a second of time, its effects may be considered as instantaneous, within any moderate distance; but sound, on the contrary, is transmitted only at the rate of 380 yards in a second. By accurately observing the time, therefore, which intervenes between the flash and the noise of thunder which succeeds it, a very near calculation may be made of its distance.

The discovery of Dr. Franklin, which ascertained the identity of lightning and the electric fluid, suggested to the same philosopher the means of preserving buildings from lightning, by means of metallic conductors attached to the outside of high buildings. As these are now so common, it is unnecessary to describe them. The principle on which they are constructed is the well-known fact of metallic bodies being better conductors of the electrical fluid than any others. The conducting rod is pointed at the top, in order the more gradually to attract the electricity from the clouds and the atmosphere; and the upper part should be made of copper, to prevent its rusting, and the remainder should be painted. The conducting rod should not be too slender, and should extend in the earth beyond the building, to convey the electric matter clearly away, and if it terminates in a pool of water, which is one of the best conductors, it will be still safer.

After this great discovery electricians began to apply the theories of electricity to a great variety of other phenomena. Thus it has been attempted to account upon these principles for the rising of vapours in the atmosphere, and the fall of rain. Previous to rain, it is supposed that a quantity of electric matter escapes from the earth, and in its ascent to the higher regions of the air, collects and conducts into its path a great quantity of vapours. The same cause that collects

will gradually condense them, till they come almost into contact, so as to form small drops too heavy to be supported by the air, and then uniting with others as they fall, come down in rain.

Hail is supposed upon the same principles to be formed in the higher regions of the atmosphere, where the cold is intense, and where the electric matter is very copious. In these circumstances a great number of watery particles are brought near together, where they are frozen; and in their descent they collect other particles, so that the density of the hail-stone is less at the surface than near the centre. And agreeably to this theory it is found, that on the tops of high mountains both the hail-stones and drops of rain are very small, owing to the little space through which they fall. Clouds of *snow* differ from the clouds which produce rain only in the circumstance of their being frozen in the upper regions. The regularity in which the flakes are disposed is used as an argument to shew that they are acted upon by some uniform cause like electricity.

It is no small confirmation of this theory, that vapours seldom rise to a great height without producing luminous meteors. Almost all volcanic eruptions are also accompanied by lightning. The column of vapour which rises from the volcano is continually traversed by lightning in different directions. Waterspouts are known also frequently to emit flashes of lightning, and to be accompanied by thunder; from which circumstance some have accounted for them, too, upon electrical principles.

The aurora borealis (or northern lights) is generally regarded as an electrical phenomenon; and is supposed to be produced by the electrical fluid being condensed in passing the columns of elevated vapour.

From all this it may be inferred, that if electricity is not the immediate cause, it is always strongly connected with the phenomena of the atmosphere; and these facts seem also further to indicate, that if the electrical fire is not indentically the same as common elementary fire, it is at least a combination of that fluid with some other unknown substance.

LESSON THE FIRST.

CONDUCTORS.

1. Electricity is that power which certain bodies possess, when excited by friction, of attracting light substances.

Example.—Amber, sealing-wax, resin, glass, &c. when rubbed pretty briskly with the hand, or a woollen cloth, will attract light bodies, as bits of paper, feathers, &c.

2. The earth and all bodies with which we are acquainted are supposed to contain a certain quantity of fluid or fluids, called the electric fluid.

3. The quantity belonging to all bodies in their common state is called their natural share, and produces no sensible effect.

4. There are two opinions respecting electricity, the one supposes there are two distinct fluids, viz. the vitreous and resinous, so named from glass and resin, which produces them by friction:—the other opinion, and more rational, admits of only one fluid, or one kind of electricity.

5. When bodies hold their own natural quantity undisturbed, they are said to be non-electrified; but when they possess more or less than their natural share they are said to be electrified.

6. When a body contains more fluid than its natural quantity, it is said to be *plus* or positively electrified; and when it contains less than its natural quantity it is said to be *minus*, or negatively electrified.

7. All bodies with respect to electricity are either conductors or non-conductors.

8. Bodies that transmit the electric fluid are called conductors, and those which will not transmit the electric fluid are called non-conductors or electrics.

9. Metals, charcoal, water, and other fluids, except oil, are conductors of electricity: glass, resin, wax, sulphur, silk, &c. are non-conductors, and may be excited by friction.

EXPERIMENTS.

(1.) If I take a clean and dry glass tube, and rub it up and down several times with a dry piece of flannel, the tube is said to be excited, and if presented to any small light substances, it will attract and repel them alternately.

(2.) If the tube be excited in the dark, and the knuckle presented, a spark will be seen passing between the finger and tube, accompanied with a snapping noise and the sensa-

tion of pain. The noise and sensation in this experiment, and the attraction and repulsion in the other, are electrical effects.

(3.) If a small pith ball, suspended on a silken thread, be brought near the tube when excited, it will attract it, and the ball will be positively electrified, that is, it will have more than its natural share: if another ball be treated in the same way, and then the two brought near together, they will repel one another. Which proves that bodies similarly electrified repel each other.

(4.) If a roll of sealing-wax or other resinous substance be excited, and a pith ball be brought near it, the ball will be attracted; and if another be placed in the same situation, and then the two brought together, they will repel one another.

(5.) If a ball electrified by the glass tube be placed near one that is electrified by the wax or resin, then the two balls will attract one another. Which proves that bodies dissimilarly electrified attract one another.

Explanation.—It is supposed that the glass tube by being excited possesses more than its natural share of the electric fluid, part of which it gives to the ball brought near it: and that the wax or resin by excitation has less than its natural share, and takes away a part of that contained in the ball placed near it. When these balls are brought together they attract one another in order that the one that has more than its natural share may give the superabundant quantity to the other that has less than its natural share.

(6.) If an oblong piece of metal, such as an iron skewer, be suspended on a silk string, and the excited glass tube be brought near one end, the other end of the skewer will exhibit the same phenomena as the tube, which proves that the electric fluid passes through the metal. This will not be the case if a stick of wax be used instead of the iron, shewing that wax is not a conductor of the fluid.

10. When a conductor is surrounded by, or suspended or placed upon, non-conductors, it is said to be insulated.

11. Positive and negative electricity always accompany one another; for if a substance acquire the one, the body with which it is rubbed acquires the other.

12. If one part of a conductor receives the electric fluid, the whole substance is pervaded with it: but if a non-conductor be presented to an electrified body, it becomes electrified in one small spot only.

13. If to one side of a non-conductor, as a glass jar, positive electricity be communicated, the opposite side will be negatively electrified, and the jar is said to be charged.

14. The positive and negative electricities may be brought together, if a communication be made between them by conductors.

15. When the two electricities are brought together their virtues are destroyed, and the act of their union is called the electric shock.

QUESTIONS FOR EXAMINATION.

1. What is meant by electricity?
Give the examples.
2. Do all bodies contain a portion of the electric fluid?
3. What is meant by the natural share of electricity?
4. What are the different opinions with regard to electricity?
5. When are bodies said to be non-electrified, and when electrified?
6. When is a body said to be positively, and when negatively electrified?
7. How are bodies divided with regard to electricity?
8. What is meant by conductors and non-conductors?
9. Mention some of the conducting and some of the non-conducting substances.
Can you describe the experiments?
10. When is a body said to be insulated?
11. Do the two electricities accompany one another?
12. What is the difference in the effect of the electric fluid being received by a conductor or non-conductor?
13. When is a jar said to be electrified?
14. How can the electricities be brought together?
15. What is meant by an electric shock?

LESSON THE SECOND.

ELECTRICAL MACHINES.

1. Machines have been contrived for rubbing together electrics and conductors, and for collecting the electric fluid from surrounding bodies: these are called electrical machines.

ILLUSTRATION.

Fig. 1. represents an electrical machine and conductor: L M is a glass cylinder, turned by a handle B against a rubber C, to which is attached a piece of silk D. By the friction of the glass against the rubber the electricity is collected and carried to the conductor E. The rubber C is fastened on a glass pillar G, and the cylinder L M and conductor E are insulated; therefore before the machine can be worked with effect, a chain is hung on the knob Z, which reaches to the ground, and by means of this chain the electricity is collected, for the rubbber having parted with all it has, is supplied from the ground.

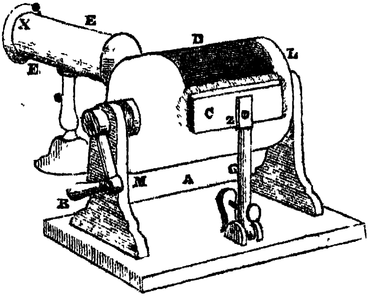


Fig. 1.

2. Some electrical machines are fitted up with two conductors, one is in contact with the cushion, and the other in the situation already described; when the machine is worked they are in opposite states of electricity, the one at the cushion being negative, and the other positive.

EXPERIMENTS.

(1.) If an ostrich's feather be placed in a hole at X of the conductor E, and the machine worked, the parts of the feather will endeavour to avoid each other and stand erect, because the several filaments being electrified with the same electricity repel each other.

(2.) If figures, cut out in paper, be laid on a brass plate, and stand under the conductor E, and another brass plate be suspended from the conductor, about two or three inches above them, and the machine worked, the figures will leap up and down till they have discharged the upper plate and conductor of their electricity.

(3.) If two small balls made of cork or of the pith of elder be fastened to silken threads, they will hang parallel to each other and be in contact, but if brought near the electrified conductor, they will strongly repel each other.

By applying an excited stick of wax to the balls while in a repelled state, it is known whether the electricity be positive

or negative; if positive the wax will bring them together, if negative it will make them recede still farther.

3. If a body containing only its natural share of electricity be brought near any thing that is electrified, a part of the electricity will force itself through the air in the form of a spark.

Experiment.—Let a person bring his knuckle near the conductor of an electrified conductor E.

4. When two bodies electrified, the one positivel, and the other negatively, approach each other, the superabundant electricity of the one will rush violently to the other to restore the equilibrium.

5. If any number of persons be so situated as to form part of the circuit, the electricity in passing through them, produces a sudden and violent effect, called an electrical shock.

6. The motion of electricity, in passing from a positive to a negative body, is so rapid, that it may be said to be instantaneous.

7. Electricity communicated to glass does not spread beyond the spot where it is thrown, owing to the nonconducting quality of glass.

8. Electricity may be communicated to the whole surface of any glass, or to any given part of it, if it be covered with a metallic substance, as tinfoil. This is called coating the glass.

9. A glass jar. coated about three parts over, leaving the upper rim two or three inches deep, quite free from coating, is called a Leyden jar.

EXPERIMENTS.

(1.) If a communication be made, by means of a chain, from the conductor to the inside of a Leyden jar, while it stands on a table, the jar will be charged: the inside being positively, and the outside negatively electrified. If a communication be made between the coating on the outside, and that in the inside, the equilibrium will be instantly restored.

(2.) A shock may be taken by putting one hand to the outside coating, and bringing the other in contact with the inside.

(3.) Any number of persons may receive the shock at the

same instant, by laying hold of each other's hands, the person at one end touching the outside of the jar, and the person at the other end bringing his hand in contact with the inside.

10. Several Leyden jars connected together by making a communication between all the outsides and another between all the insides, form an electric battery.

11. By means of an electric battery very powerful effects may be produced.

EXPERIMENTS.

(1.) A slender harpsichord wire being made part of a circuit, will, by the discharge of the battery, instantly become red hot, and sometimes melt.

(2.) Gunpowder may be inflamed by the electrical battery.

(3.) If a quire of writing paper be suspended by a string, and two ends of a conducting wire be brought near each side of it, and the circuit completed, on discharging the battery the electric fluid will pierce a hole through the paper without putting it in motion.

12. It is ascertained that lightning and electricity are the same, that is, lightning is the rapid motion of vast masses of the electric matter; and thunder is the noise produced by the motion of lightning.

13. Metallic points silently attract electricity from bodies charged with it; hence the use of pointed wires as conductors to secure buildings from the effects of lightning.

14. The Auroræ Boreales, or northern lights, are the effects of the electric fluid passing through highly rarefied air.

15. Earthquakes, whirlwinds, water-spouts, &c. are generally accompanied with, and dependant upon, electrical phenomena.

16. There are three kinds of fish, viz. the Torpedo, the Gymnotus Electricus, and the Silurus Electricus, that are possessed of the power of giving shocks similar to those experienced from the Leyden jar.

17. Electric sparks and electric shocks have been applied to the cure of deafness, paralytic affections, inflammations, &c.

QUESTIONS FOR EXAMINATION.

1. What are electrical machines?

Can you give the illustration.

2. Have any machines more than one conductor, and how are they situated?

3. How is the electric spark obtained?

What is the experiment?

4. How is the equilibrium of two bodies, differently electrified, restored?

5. In what way can any number of persons receive the electrical shock?

6. Is the motion of electricity very swift?

7. Does electricity spread on glass?

8. Can it be made to communicate with the whole, or with any part of the surface of glass?

9. What do you mean by a Leyden jar?

Mention the experiments?

10. How is an electrical battery formed?

11. Can considerable effects be produced by an electrical battery?

What are the experiments?

12. What are lightning and thunder?

13. Why are pointed wires used to secure buildings from the effects of lightning?

14. By what are the Auroræ Boreales produced?

15. Do earthquakes, &c. depend at all on electricity?

16. Which are the electrical fish, and what property do they posses?

17. Has electricity been applied in medicine?

GALVANISM, OR VOLTAISM.

WHAT IT EMBRACES.

"The discoveries of Franklin displayed the influence of electricity in the production of the most magnificent phenomena of nature. That of VOLTA has led to the development of its connexion with her more silent, but important processes. Like the power of gravitation, it seems to apply more extensively the farther its investigation is pursued. Like that power too, its nature may for ever escape our cognizance; but the contemplation of its effects may supply new facts calculated to extend the resources of art, and enlighten our conception of the infinite variety and harmony of natural phenomena. Such pursuits are amongst the best sources of intellectual improvement, for they call into action the highest powers of the mind, and present a constant succession of interesting objects for their exercise."

Singer's Elements of Electricity and Electro-Chemistry.

GALVANISM is a term used to designate a recently discovered, but very extraordinary power, which metals display and exert, by mere external contact with the animal body. In the year 1791, a very remarkable discovery made by DR. GALVANI, of Bologna, was announced to the scientific world in a publication entitled "Aloysii Galvani de Viribus Electricitatis in motu musculari Commentarius."

The discoveries of Galvani were made principally with dead frogs. He in the first place discovered that a frog dead and skinned, is capable of having its muscles brought into action by means of electricity, even in exceedingly small quantities. Secondly, that independently of any apparent electricity, the same motions may be produced in the dead animal, or even in a detached limb, merely by making a communication between the nerves and the muscles, with substances that are conductors of electricity.

Galvanism or Voltaism, therefore, embraces the phenomena which result from different conductors of electricity, being placed under different circumstances of contact. The conductors must be either perfect or imperfect conductors of electricity: and the Galvanic phenomena may be produced by two conductors of one of these classes placed in contact with each other, in one or more points, and in other distinct points with a conductor of the other class: thus gold and zinc may be made to touch each other, in some points, and may be connected in other points by a portion of common water.

To produce the Galvanic phenomena with any considerable effect, several series of conductors, thus disposed, should be employed. Then, not only may an acid taste, a flash of light, the contraction of muscles just detached from a living body, the oxidation of metals, and the decomposition of acids and of water, be produced; but shocks on the human body analagous to the electric shock, and brilliant sparks with the deflagration of even silver and gold, may also be occasioned by this fluid under certain circumstances. Fabroni, in Nicholson's Journal for 1800, noticing the oxidation of metals while under Voltaic influence, concluded it to be a chemical phenomenon merely. In this year VOLTA announced his discovery of the Galvanic pile, formed by plates of two different metals, as zinc and silver, disposed alternately with moistened pasteboard between them. By connecting the ends of the pile by the hands, he obtained a strong shock, and produced many curious experiments. Mr. Nicholson in the same year employed much of his ingenuity in examining these phenomena, and devoted a considerable portion of his journal to their investigation. By making a tube of water form part of the line connecting the two ends of the pile, he found, from the wire passing into the water from the silver end, hydrogen separated; whilst the other, if an oxidable metal, became oxidized; but if platina, he found oxygen was evolved. Thus was ascertained its chemical action, and its powers of decomposing water.

But the most important discoveries in Voltaism were made by Sir Humphrey Davy. They, however, would of themselves fill a volume, and cannot be here detailed.

LESSON THE FIRST.

GENERAL PRINCIPLES.

1. Galvanism, which seems to be another mode of exciting electricity, derives its name from Galvani, who made the earliest discoveries on the subject.

2. Electrical phenomena are chiefly excited by friction; but the effects of Galvanism are produced by the chemical action of bodies upon each other.

3. Galvani first discovered that a dead frog may have its muscles brought into action by very small quantities of electricity.

4. He next observed that similar motions may be produced on dead or on living animals by making a communication between the nerves and muscles, by means of conducting substances, as metals of different kinds.

5. The diversity of the metals employed, appeared in the very earliest stages of this inquiry, to be connected with their respective degrees of oxydability,* the one being possessed of that property in a great degree, while the other is little liable to the change. Hence, zinc and silver were found to produce the greatest muscular contractions.

EXPERIMENTS.

(1.) If a person place a half-crown upon his tongue, and a plate of zinc under it, and bring the outer edges into contact, he will perceive a kind of acid taste.

(2.) If a frog or flounder, having a slip of tin-foil pasted upon its back, be placed upon a plate of zinc, and a communication be formed between the zinc and tin-foil, convulsive motions in the animal will be excited.

6. The electrical phenomena, convulsions, &c. exhibited by Galvanism are to be ascribed to common electricity, excited by the different metallic conductors.

7. Conductors in Galvanism are divided into the perfect and imperfect.

8. Perfect conductors consist of metallic substances and charcoal. Imperfect conductors are water and the oxydating fluids, as the acids, and indeed all substances that contain these fluids.

9. Every galvanic combination must consist of three different conductors, not wholly of one class, and the conductors of one class must have some chemical action upon those of the other.

ILLUSTRATION.—In the first experiment the three conductors were the silver, the zinc, and the saliva, and the action of the metals upon one another decomposed the water† contained in the saliva, the oxygen combining with, and oxydating the zinc produces the effect.

* See Lessons on Chemistry for the meaning of this and similar terms.

† Water, as will be noticed hereafter, is a compound of oxygen and hydrogen gases.

10. If a round piece of zinc be laid on a piece of copper, each about two inches in diameter, and then a similar piece of flannel moistened with a solution of salt in water, and on these other layers in the same order, and so repeated several times, the whole will form a Galvanic pile, with which such experiments as the following are made. See fig. 2, p. 312.

EXPERIMENTS.

(1.) If the circle be completed by bringing one hand to the zinc at bottom, and the other to the copper of the upper layer, an electric shock will be felt.

(2.) If the circle be completed by a wire attached to the lowest plate of zinc and carried from thence to the upper copper, sparks will be given out.

(3.) By the same mode, if the pile be sufficiently powerful, very fine wire will be made red-hot, or even fused, so will gold leaf.

(4.) Electric batteries have been charged with the galvanic pile; and mixtures of oxygen and hydrogen gases may be exploded by it.

11. From these, and other experiments of the same nature, it has been inferred that the electric and galvanic fluids are the same.

12. Sometimes silver is used instead of copper: and it is ascertained that the zinc end of the pile is always positive, and the silver and copper always negative.

13. The zinc end of the pile is supposed to give out the electric fluid, which enters at the silver or copper end.

14. It is proved that chemical action is essential in Galvanism from this, that the action of the pile is most powerful in oxygen gas, and it ceases in a vacuum or in azotic gas.

15. It is supposed that all chemical action depends on the different states of bodies, that is, as to their being either in a positive or negative electrical state.

Illustration.—All acids are naturally negative, and alkalies are positive, hence their speedy union. The results are neutral salts, which are found to be neither positive or negative

Experiment.—If a neutral salt, as sulphate of soda, be

brought within the circuit of a galvanic pile, by means of wires extending to it from the zinc and copper, it will be decomposed; the acid, which is naturally negative, will be found at the positive or zinc end of the wire, and the alkali at the negative or copper end of the wire.

QUESTIONS FOR EXAMINATION.

1. What is Galvanism?

2. What is the difference of excitation in electricity and Galvanism?

3. What were Galvani's first discoveries?

4. What were his next observations?

5. With what is the diversity of metals, used in Galvanic experiments, connected?

Mention the experiments.

6. To what are the electrical phenomena exhibited by Galvanism to be ascribed?

7. How are the conductors in Galvanism distinguished?

8. Which are the perfect and imperfect conductors?

9. Of what must a galvanic combination consist?

Give the illustration.

10. Describe a galvanic pile.

Mention the experiments.

11. What is the inference drawn from these experiments?

12. Which end of the pile is positive, and which is negative?

13. Which is supposed to give out, and which to receive, the electric fluid?

14. What proof is there that chemical action is essential in Galvanism?

15. Upon what does chemical action depend?

Give the illustration and experiment.

LESSON THE SECOND.

BATTERIES.

1. The pile, already described, was invented by Volta, who is justly regarded as the founder of the science, from the importance of his earliest discoveries; and on that account, it is often, and will, probably hereafter, generally be denominated "Voltaism."

2. Another kind of Voltaic battery consists of a row of glasses or china cups, fig. 3, p.312, containing a solution of

salt and water; into one of the glasses, on the outer side, is put a plate of zinc fastened to a piece of wire made to bend over into the other cup, and to the other end is put a plate of silver: this is to be repeated with respect to all the glasses, so that each one will contain a plate of zinc and a plate of silver united with wire, except the outer glasses, in one of which will be a plate of zinc and in the other a plate of silver.

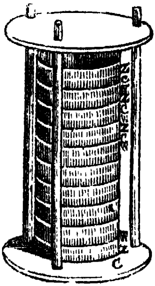


Fig. 2.

Explanation.—Fig. 2 represents a galvanic or voltaic pile, and fig. 3 a voltaic battery with glasses. In the former the letters Z C W are supposed to stand against the plates of zinc, copper, and moistened flannel; if a wire be placed at the lower, C, and another at the upper, Z, and brought together, the galvanic circle is complete.

In fig. 3, the letters *z* and *s* represent the plates of zinc and silver connected by wires *w*. By dipping one end in the glass *z*, and at the same time the other in the glass *s*, the circle is complete, and a galvanic shock is felt. Any number of glasses may be used, and the greater the number the more intense the shock.

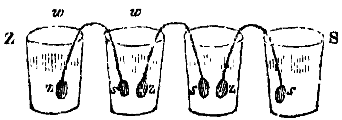


Fig. 3.

Experiment.—By means of the pile, fig. 2, water is decomposed: when silver is used instead of copper, and brass wires brought from the upper and lower plates to a drop of water, hydrogen gas was evolved at the silver end, and the other wire was oxydated by uniting with the oxygen.

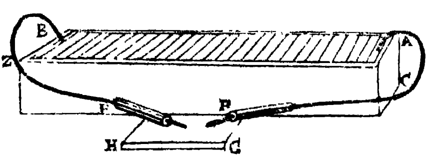


Fig. 4.

3. A battery of a more convenient kind consists of a trough, A B, fig. 4, made of baked wood, it is about three or four inches deep and as many wide. In the

sides are grooves opposite each other; into each pair of grooves is fixed by cement a plate of copper and a plate of zinc. The cells are then filled with a solution of salt and water, or what is still better, with a solution of nitrous or muriatic acid and water. The edges of the trough and plates are to be wiped very dry, so that there be no communication between the separate cells by moisture; and the trough is then fitted for experiments.

EXPERIMENTS.

(1.) If one hand be put in the trough at A, and the other at B, a severe shock will be felt.

(2.) If several persons join hands, with their hands previously moistened, and the two outer persons put their hand into the troughs as before, they will all feel a shock.

(3.) If new wires be attached to the two outer cells, the one to the zinc end, plate Z, and the other to the copper end, plate C, and by means of two small pieces of glass tube, E and F, the wire be brought into contact, a vivid spark will be given out; and if between them, on the glass pane G H, gunpowder, or charcoal, or gold-leaf, &c. be placed, they will be instantly inflamed.

Copper or brass leaf, commonly called Dutch gold, burns with a beautiful green light; silver leaf with a pale blue light; and gold leaf with a yellow light.

4. Several of these batteries may be united by iron cramps so as to act as one: the troughs are now constructed of the Wedgewood ware, and the plates made to move up and down for the convenience of experiments.

5. By means of these batteries the alkalies, some of the earths, sulphur, and other bodies, have been decomposed, which were, till lately, considered as simple bodies.

6. The limbs of people under amputation are sometimes convulsed by the application of the instruments, which is an effect of Galvanism.

7. Pure mercury retains its splendour a considerable time, but the amalgam of mercury with tin, or any other metal, soon becomes tarnished or oxydated, which is imputable to the galvanic action of the two metals.

8. Metallic works, the parts of which are soldered

together with other metals, soon oxydate about the parts where the different metals are joined, which is an effect of Galvanism.

9. In the sheathing of ships with copper where iron nails are used, the copper about the nails is quickly corroded.

10. Zinc may be kept in water a long time without much oxydation; but the oxydation goes on rapidly when there is silver or copper in contact with it.

QUESTIONS FOR EXAMINATION.

1. By whom was the pile invented, and on what account is this science called Voltaism?

2. Describe the battery made with glasses.

Give the explanation of the pile and glasses by means of the figures.

Explain how water may be decomposed.

3. What is the construction of the galvanic trough?

Give an account of the experiment.

4. How are several troughs made to act as one, and with what substance are these troughs made?

5. What effects have been produced by these batteries?

6. To what have the convulsive spasms experienced in surgical operations been ascribed?

7. Explain why amalgams soon become tarnished?

8. What parts of metallic works, in which different metals are used, are the soonest oxydated?

9. Where does the sheathing of ships soonest corrode?

10. In what manner may zinc be kept under water without corroding, and how will it rapidly corrode?

MAGNETISM.

THE BASIS OF THE SCIENCE.

"The magnet acts upon iron through all dense bodies not *magnetic*, nor red-hot, without any diminution of its virtue; as through gold, silver, lead, glass, water."—*Newton's Optics.*

"Magnetism coincides with electricity in so many important points, that the existence of two *magnetic* ethers, as well as of two electric ones, becomes highly probable."—*Darwin.*

I BUT anticipate the definitions of the following lesson, when I state that the natural magnet, or the loadstone, is a hard mineral body of a dark black colour, and when examined is found to be an ore of iron. It is met with in various countries, generally in iron mines, and of all sizes and forms.

This singular substance was known to the ancients; and they had remarked its peculiar property of attracting iron, though it does not appear that they were acquainted with the wonderful property which it also has, of turning to the pole, when suspended, and left at liberty to move freely.

Upon this remarkable circumstance, the mariner's compass depends, an instrument which gives us such infinite advantages over the ancients. It is this which enables the mariners to conduct their vessels through vast oceans, out of the sight of land, in any given direction; and this directive property also guides the miners in their subterranean excavations, and the travellers through deserts, otherwise impassable.

It is not precisely known when, and by whom, this directive property of the magnet was discovered. The most probable accounts seem to prove, that it was known early in the 13th century; and that the person who first made mariners' compasses, at least in Europe, was a Neapolitan of the name of Flavio, or John de Gioga, or Giova, or Gira.

This science may justly be considered as yet but in its infancy, although the facts elicited since the commencement of the 19th century by Davy and others, exhibit a promise, and bid fair to throw considerable light on some of its more recondite principles. The theory of magnetism bears a very strong resemblance to that of electricity. In that science we see the electric fluid not only exerting attractions and repulsions, and causing a peculiar distribution of neighbouring portions of a fluid similar to itself, but we also see it excited

in one body and transferred to another in such a manner as to be perceptible to the senses, or at least to cause sensible effects in its passage. The attraction and repulsion, and the peculiar distribution of the neighbouring fluid, are found in the phenomena of magnetism; but we do not perceive any actual excitation or perceptible transfer of the magnetic fluid from one body to another; and it has also this striking peculiarity, that metallic iron is very nearly the only substance capable of exhibiting any strong indications of its presence.

LESSON THE FIRST.

GENERAL PRINCIPLES.

1. The natural magnet or loadstone is a hard mineral body, of a dark colour, and found to be an ore of iron, discovered in iron mines.

2. Its property of attracting iron was known to the ancients, but its more important property, applied to navigation, was discovered only a few centuries ago.

3. The natural magnet can be made to communicate its properties to iron and steel, and when pieces of steel properly prepared are excited by it, they are called, "artificial magnets;" to iron the virtue is more easily communicated, but steel retains it the longest.

4. Magnetism explains the properties of the natural magnet, and shews by what means artificial ones are made.

5. All magnets attract iron, which is called their *attractive* power.

6. When a magnet is at liberty to move itself freely, it constantly turns the same part towards the north pole, and the opposite part towards the south pole of the earth. This is called the *directive* power.

7. The ends of the magnet are called the poles, which are denominated north and south according as they point to the north or south pole, and when a magnet places itself in this direction, it is said to *traverse*.

8. When a magnet is left at liberty, its two poles do not lie in a horizontal direction, but one inclines downward, and the other is elevated upwards. This is

called the inclination, or *dipping* of the magnet, or of the needle.

9. The north or the south pole of two magnets repel each other; but the north pole of the one will attract the south pole of the other.

10. The magnetic meridian is a plane perpendicular to the horizon, and passing through the poles of the magnet when standing in their natural direction.

11. If a magnet be placed on cork, and allowed to float freely on water, with no iron near it, it places itself in the magnetic meridian: it is this principle that renders it useful to seamen.

12. The natural direction of the magnet is towards the northern and southern parts, yet it seldom points due north and south; and the difference is called the declination, which is said to be east or west according as the north pole of the needle is eastward or westward.

13. The declination, in June 1808, was 24° 10′ west and the dipping of the needle at the same time was 70° 1′.

14. A steel bar, or needle, as it is usually called, fitted up in a box, so as to move freely in every direction, constitutes the mariner's compass.

QUESTIONS FOR EXAMINATION.

1. What is meant by a natural magnet?
2. Which of its properties has been longest known?
3. To what metals can the properties of the natural magnet be communicated?
4. What is the object of magnetism?
5. What is the attractive power of magnets?
6. What do you mean by the directive power?
7. Which are the poles of a magnet; and when is it said "to traverse?"
8. What is meant by the dipping of the needle?
9. Under what circumstances do the poles of two magnets repel and attract each other?
10. What is meant by the magnetic meridian?
11. What principle renders the magnet useful to mariners?
12. Does the magnet point due north and south?
13. What was the declination and dipping of the needle in June 1808?
14. What is a mariner's compass?

LESSON THE SECOND.

ATTRACTION.

1. If a piece of iron be brought within a certain distance of one of the poles of a magnet it will be attracted by it.

2. The attraction of the magnet and iron is mutual, that is, the iron attracts the magnet as much as the magnet attracts the iron.

Experiment.—Let a magnet and a piece of iron of equal, or nearly equal weights, be made to float by means of a cork on a vessel of water, at a little distance from each other; and the magnet will move towards the iron, and the iron towards the magnet. If either be kept steady, the other will move to it.

3. The attraction is strongest at the poles, and in the centre between the poles there is no sign of attraction whatever.

4. The magnetic attraction is not in the least diminished by the interposition of any bodies except iron.

Experiment.—Put a needle on a pewter plate, and it will follow the magnet which is moved on the outside.

5. When a piece of iron is brought within a certain distance of a magnet, it becomes itself a magnet: that part of it which is nearest the south pole of the magnet is a north pole in the iron, and *vice versâ*.

6. The properties of the magnet are not affected either by the presence or absence of air. It acts as well in a vacuum as in the air.

7. Heat weakens the power of a magnet: and a white heat destroys it entirely.

8. Lightning, and even the electrical shock, will often render iron magnetical.

9. The gradual addition of weight to a magnet, kept in its proper situation, increases the magnetic power.

10. Magnets should be always kept with their poles pointing to the poles of the earth: this is said to be their proper situation.

11. In the northern hemisphere the north pole of a magnet has most power: and it is said the south pole is strongest in the southern hemisphere.

12. An artificial magnet, or a magnetic needle, is made by fastening the steel on a piece of board, and drawing magnets over it several times, from the centre to the ends.

13. The power of a magnet is not diminished by communicating its properties to other bodies.

14. Two or more magnets joined together may communicate a greater power to iron or steel than either of them possesses singly.

15. Bars of iron that have stood in a perpendicular position are generally found to be magnetical.

16. The mariner's compass consists of the box, the card or fly, and the needle.

Illustration.—The box X X, fig. 1, which contains the card or fly, is of a circular form, and is made of wood, or brass, or copper; and is suspended within a square wooden box B, by means of two concentric circles, called gimballs, so fixed by cross axes, *a a a a*, fig. 2, to the two boxes, that the inner one, or compass box, shall retain an horizontal position in all the motions of the ship, while the outer or square box is fixed with respect to the ship. The card is a circular piece of paper, which is fastened to the needle and moves with it. The outer edge of the card is divided into 360 parts, or degrees, and within the circle of these divisions it is again divided into 32 parts, called the rhumbs, or points of the compass.

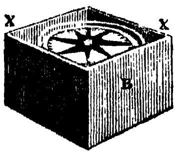


Fig. 1.

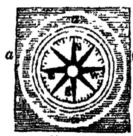


Fig. 2.

17. The azimuth compass is like the mariner's compass, with two sights adapted to it, through which the sun is to be seen in order to find its azimuth, and from thence to ascertain the declination of the magnetic needle.

18. To construct a dipping needle, an axis must be passed through the needle; the extremities of this axis

rests upon two supports, so that the needle may move itself vertically round, and when situated in the magnetic meridian, it may place itself in the magnetic line; when used at sea it is suspended by a ring.

QUESTIONS FOR EXAMINATION.

1. In what case is iron attracted by the magnet?

2. Is the attraction of the magnet and iron mutual?

Mention the experiment to prove this.

3. Where is the attraction the strongest?

4. Is the magnetic attraction diminished by the interposition of other bodies?

What experiment proves this?

5. In what situation does iron become a magnet?

6. Does the air affect the properties of the magnet?

7. Has the heat any effect on the power of the magnet?

8. How is iron often rendered magnetical?

9. How is the power of a magnet strengthened?

10. In what position should magnets be kept?

11. In which hemisphere do the poles of magnets act best?

12. How is an artificial magnet made?

13. Is the power of the magnet diminished by communicating its properties to iron?

14. Can two or more magnets communicate to iron more power than either of them possesses singly?

15. Under what circumstances are iron bars found magnetical?

16. Of what does the mariner's compass consist?

Give the illustration with the figure.

17. What is an azimuth compass?

18. What is the construction of the dipping needle?

CHEMISTRY.

THE MATTER OF HEAT.

"The basis of chemical science is the analytical examination of the works of nature, and the investigation of the properties of the several substances with which we are acquainted: it should therefore be the first concern of every chemical student to receive nothing as true, but what has actually been proved by experiment, or deduced from analogy. Let him rely upon nothing but facts, and he will be in little danger of forming extravagant or erroneous opinions. 'If we dare to investigate nature, we must *see* her and *try* her on all sides, and be sure that she still confesses the same thing.'"—*An Elementary Treatise on Chemistry upon the basis of the Chemical Catechism, by Samuel Parkes.* New edition published in 1839.

Heat and cold are to be considered either as particular sensations, or as the causes of powers which bodies possess of exciting those sensations. Thus we say that we ourselves are hot or cold, and that the fire or ice which heats or cools us is likewise hot or cold: though the sensations we experience are certainly very different things from that which enables those bodies to excite them. It must be observed that the sensations of heat and cold are very fallacious ones, in so far as they are affected by the temperature of the body in which they are excited: for we may feel a substance hot when it is in the same circumstances in which we should feel it cool at another time. To elucidate this, we may observe that when we have been accustomed to live in an atmosphere of between 60° and 70°, if the heat fall to 60° we feel it cold; but, on the contrary, if we have lived in an atmosphere of between 40° and 50°, if the heat rise to 60° we feel it very hot. Again, let two basins of water be taken, one heated only to 35° the other to 110°, and put one hand into the one, the other into the other basin, for some time; if we then immerse both hands in water heated to 60°, we shall with one hand feel the cold, with the other hot. Hence it may be reasonably inferred, that we cannot judge with precision of heat or cold by the sensations they excite in us.

In the next place, let us consider heat and cold as the cause of powers which bodies possess of exciting peculiar sensations. As to cold, it is seldom supposed to be either matter itself or a quality: it is more commonly looked upon as a deprivation of heat; for the less the heat found in a body, the greater the cold, and *vice versâ*. There are particular cases in which

cold may be produced. 1st, When some particular chemical attraction takes place, cold is produced. 2nd, The conversion of solids into liquids, and of liquids into vapour, produces cold, as is shewn by chemists. And 3rd, Cold may be produced by animal powers. I do not intend to relate experiments by which these may be proved; but the grand question which I most wish to determine is, with respect to heat, whether it be matter under some particular form, or only a quality. That our reasoning on this important subject may have the better effect, we must first reflect upon the various means of producing heat. There are several ways by which heat may be generated. 1st, By means of the sun's rays. 2nd, By exciting vibrations in solids. 3rd, By the taking place of certain chemical attractions. 4th, By conversion of vapours into fluids, and of fluids into solids. 5th, By animal powers. 6th, In volcanos. And first, if a cold body be exposed to the rays of the sun, it will be heated.

It has been frequently conjectured that the sun is fire, burning and heating other bodies in like manner as ordinary fire: but the celebrated Dr. Fordyce asserted, that the sun is probably not at all hot in itself; neither are the solar rays hot, but have only a power of producing heat on being applied to other bodies. An opinion very little different from this was also entertained by Dr. William Herschel, and supported with the authority of demonstration. As a farther consideration of this subject may tend to correct our notions concerning light, I shall here attempt it.

It is a constant rule with regard to hot bodies that they heat all colder bodies which are brought near them. Though it must be allowed that some bodies will receive heat with more readiness than others: however, this will not easily form an objection to what immediately follows.

Now, if we take a large burning glass, and hold a piece of iron in its focus, such heat will be produced as to melt the iron. But the glass through which all the rays passed is scarcely heated at all: and when they fell on the iron they were no hotter than water when it is poured on vitriolic acid. But if we place water which is perfectly transparent in the focus, no heat will be produced, nay, if spirits of wine were placed in the focus, they would scarcely be heated. But the same heat which melts iron, would more than suffice to make water boil. From this experiment then, without advancing farther arguments, it appears that the rays in themselves have no heat; and there is no reason to suppose that the sun is hotter than the earth we inhabit.

It is a question that has been much agitated, whether the solar rays be matter, or only an arrangement of matter; but their materiality is now pretty generally admitted: but a question which has not yet been satisfactorily answered is, "If light be matter, what becomes of it?" Perhaps there is a distinction between light and the solar rays, which has not yet been properly attended to.

The sun's rays heat bodies only when they are bent or destroyed. The term *absorbed* does not in my opinion exactly answer the purpose. Hence, they do not heat water if perfectly transparent; neither do they heat the air above the clouds: at least, as very little bending takes place in these cases, the heat is so trifling as to be scarcely worth mentioning. The upper regions of the air then, are extremely cold, though exposed to the direct action of the sun. When a ray of light is reflected, it does not *touch* the body reflecting it, but is thrown back before it arrives at the surface: therefore, the more white bodies are, or the more highly they are polished, the less they are heated, because they reflect more of the rays: and when a body is perfectly white it reflects all the light, and is not heated at all. Bodies, in proportion as they deviate from white, destroy the more solar rays, and a perfectly black body would destroy them all: hence bodies are more heated, as they are darker coloured, by this cause of heat.

When a body is rough, as if we make a piece of glass so which may have no colour, it destroys part of the rays, or at least suffers them to approach so near its surface before it reflects them, that they cause it to be heated. Thus far our reasonings induce us to suppose that *heat* is a *quality:* but heat, as a quality, cannot exist without a substance to exist in. So that, if it were possible to produce a *perfect vacuum*, there could be no heat therein. This also leads us to conclude, that the denser a body is, the more heat may be therein produced; other circumstances being the same.

Heat, it is affirmed, can only be produced by the solar rays at the surfaces of bodies; consequently the interior parts can only be heated by communication. And if we keep in mind that heat is more readily transmitted, communicated, and received by some bodies than others, it will then appear that, as a body receives heat with more facility, it will be the more heated by the sun's rays; as a piece of iron will be more heated than a piece of wood.

We have seen then, that the solar rays are not hot in themselves, that they produce heat only when they are bent or

destroyed; that, therefore, they do not heat transparent bodies, nor do they heat in passing through them, but only at their entrance and passing out again.

It is evident, since the rays of the sun have a power of producing heat, that they will heat a body more, the greater the quantity is that falls on it. From this principle, combined with some particular circumstances, arises the different heat and cold of the seasons, and of the different parts of the earth. For instance, the heat about the equator has been known to rise to 110°, and it is said, that the cold in Siberia has been as low as 160°: but the accuracy of this may be doubted, for I do not see how so great a degree of cold can be precisely measured.

The heat produced by the solar rays is increased also by the reflection of them: if they be frequently reflected, a greater heat is produced than even if they be all destroyed. Thus we find that, if we receive them into a box so constructed as to reflect them frequently from side to side, more heat will be produced than in a box made black, so as to destroy them almost all. Hence in valleys, even in temperate climates, where the rays are reflected frequently, very great heat is also produced.

The different distances of the planets from the sun, it is imagined, makes a great difference in the number of the rays, and in the *momentum* with which they fall on them. So that it has been thought the Mercury is exceedingly hot, and the Georgium Sidus or Herschel cold beyond conception: but since the heat produced in bodies depends on their disposition to receive it, the several planets may be so composed as to have but a very trifling difference in the heat produced by the solar rays. Hence, then, what has been hitherto said concerning the heat of the planets as calculated on the supposition of the sun being the source of heat, may be called in question: and, perhaps the Newtonian opinion concerning comets, may in time be entirely abandoned, and some later hypothesis become generally received.

Thus much for the first method of producing heat. The next method of producing heat is by exciting vibration in solids. Whether fluids can be thus heated, we do not know: there is no clear instance of heat being produced by their vibration. We may excite vibration in solids, by friction, or by collision. If we rub together or strike two bodies, if they have any elasticity they will vibrate. The rougher bodies are, which are rubbed together, the greater vibration is pro-

duced, and therefore, the greater heat. The vibration is also in proportion to the elasticity of bodies.

In Count Rumford's ninth Essay, which is an enquiry into the source of the heat that is excited by friction, many interesting experiments are related. From these experiments it appears, that sufficient heat was produced by the friction of two metallic surfaces, when the access of atmospherical air was entirely prevented, to make water actually boil. It appeared that a very considerable quantity of heat was excited by the friction, and given off in a constant stream *in all directions*, without interruption or intermission, and without any signs of diminution or exhaustion.

This ingenious philosopher, when reasoning on these experiments, gives satisfactory reasons to prove that the heat could not be furnished either by the air, or by the water which surrounded the machinery. And, considering that the source of the heat generated in these experiments appeared evidently to be *inexhaustible*, he naturally concluded, that *heat* could not be *matter*: for says he, "It is hardly necessary to add, that any thing which any *insulated* body, or system of bodies, can continue to furnish *without limitation, cannot possibly be a material substance*."

Another method of producing heat is by the taking place of chemical attractions. Every chemical attraction, as far as we know, in taking place, produces either heat or cold: whether it be simple combination, elective attraction, or compound elective attraction. Some of the chemical attractions are attended, besides the production of the heat, with another striking phenomenon, namely, the producing of light. The fourth and fifth methods of producing heat might be descanted upon very copiously; but, perhaps, this would have but little tendency towards determining what heat is.

Lastly, heat is produced in volcanos. This has commonly been supposed to be by burning of fuel. But it is evident that it cannot be *produced* by this cause, or by any other known means of the production of heat. The burning of fuel, it is known, destroys a proportionate quantity of air. Now the whole island of Santalina is a mass of iron, one very difficult of fusion, which was fused and thrown up from the bottom of the sea in the midst betwixt two shores, by this heat; where no air could, therefore, possibly come. And if it could, it would have required more in quantity than would have exhausted the whole atmosphere, to animate fuel enough to have produced the heat. In Friesland, some years ago, there was a tract of country 100 miles across, the whole of

which, with men, animals, trees, and whatever was on it, was melted into one common mass. This heat then cannot be produced by the burning of fuel; much less can it be by the decomposition of pyrites, which is, indeed, the burning of sulphur. And by what means such intense heat is produced we are at a loss to determine.

Having spoken of the various methods of producing heat, I must next observe, that bodies may be heated by communication; and several experiments might be described to shew, that some bodies will both communicate and receive heat more readily than others. It is the same with respect to cold as to heat; for those bodies which receive heat most readily, most readily part with it; and if they do this, they must also suffer it to pass through them, speaking of it as though it were a body, from one substance to another, or conduct it most readily, and *vice versâ*.

Iron is a good *conductor* of heat: on the contrary wood is one of the best non-conductors of heat known. That the former is a conductor, and the latter a non-conductor of heat, is evident from the following simple experiment; if you take a nail or a small piece of iron, and hold it in the flame of a fire or candle, it will speedily become so hot all over, as to oblige you to relinquish your hold: but if you take a small piece of wood, and hold it in the flame, you may keep hold of it till it is nearly all consumed by the fire, without being incommoded by the heat of the wood. Hence heat passes with ease in iron, and with difficulty in wood.

From the results of various experiments Count Rumford concludes that water, oil, mercury and air, are non-conductors of heat: indeed, he thinks it essential to all fluids, that they should be non-conductors of heat, or that all interchange and communication of heat among their particles, as from one of them to the other, is absolutely impossible. Glass, when rendered of a loose texture, conducts heat with very great difficulty; insomuch, that the lava of a volcano has, sixteen years after an eruption, been found red-hot a foot under the surface of such glass, though this was quite cool. This circumstance might very probably give the hint for the assertion, paradoxical as it may seem without proper deliberation, that it would be no difficult matter to convey an iron ball red-hot from London to Lincoln: to perform this it must be inclosed in pumice-stone, which is very porous glass, formed by volcanos, and then covered over with fur.

As to the effects produced by heat, it is known to expand bodies; and some late chemists affirm, that it tends to

diminish every attraction we are acquainted with: they produce experiments to evince that heat diminishes the attraction of gravitation, of cohesion, of magnetism, of electricity, and chemical attractions. But though it may be the case in particular instances, it will be better not to be too sanguine in imagining that such effects will take place *universally*. The assertion may be disputed with regard to the attraction of gravitation and electricity. However, those who allow that heat universally diminishes the electrical attraction, will strongly contend in support of their opinion, because they may thereby explain with facility the reason of the frequency of thunder-storms in summer.

From a review of what I have here advanced we shall find that there are few, or perhaps we may confidently say, no appearances, but what will admit of as easy an explanation, by conjecturing that heat is a quality, as by supposing that it is a substance. Nay, some of the phenomena, particularly those which attend the productions of heat by friction, or vibration in solids will, as must appear from what has been previously observed, induce us to incline more to the former hypothesis than to the latter. Besides, whether heat be a substance, or a quality, it is manifest that it may be created and annihilated. Now we have no idea of matter being created and annihilated by any natural cause, for under all its variety of forms, matter is matter still: then what kind of substance must heat be, to be produced and destroyed by so many causes? Why truly nobody can tell: for it must have a property which matter has not. Heat is then, probably, a *quality*: for qualities we know can easily be created and annihilated. And, if heat be a quality, it must have matter to exist in; so that, if we apply any of the causes producing heat, no heat is produced unless there be some matter to receive it. This, therefore, is the result of our enquiries into the nature of heat.

We have also seen that light may be produced by particular means, the solar rays for instance: it may likewise be destroyed, as has been previously shown. The method of reasoning first applied to heat, may with equal propriety be used here: and this will induce us to conclude, that light instead of being a *fluid per se*, as has been sometimes conjectured, is a *quality*, and can no more exist independently of matter than heat can.

Whether these conclusions may be safely relied on, is not for me to determine: the great mysterious Being who made and governs the universe, has set a part only of the chain of

causes in our view; and we find that as He himself is too high for our comprehension, so His more immediate instruments are also involved in an obscurity that our feeble endeavours are not able to dissipate.

LESSON THE FIRST.

ATTRACTION. CALORIC.

1. Chemistry is the science which investigates the effects of the action of bodies upon each other, to determine their constituents principles, and to form new compounds. The term chemistry is derived from the Greek word *chumos* or *chew*, which signifies to melt, and may be defined to be the science which investigates the composition of material substances, and the permanent changes of constitution which their mutual actions produce: or an art whereby sensible and natural bodies are so changed, chiefly by the agency of fire, as to enable us to discover their several and peculiar powers and properties, either in their simple or compound state."*

Illustration.—The utility of chemistry is shewn by its connexion with the arts of life: the arts of dying, bleaching, tanning, glass-making, and the working of all kinds of metals are purely chemical. In agriculture it explains the phenomena of the growth and nourishment of vegetables, and the nature and action of manures. In medicine its assistance is peculiarly valuable, nor is it of small importance in the culinary arts. There is scarcely a single trade or manufacture, that does not depend, either immediately or more remotely, upon a knowledge of this science.

2. That power which tends continually to bring substances together which are disunited, and which retains, with more or less energy, those which are already in a state of combination, is called elective attraction, or attraction of affinity.

3. Affinity of aggregation is that which exists between two particles of the same matter.

* Elementary Treatise on Chemistry. New edition, published 1839.

Examples (1.) Two drops of water running together form an aggregate. Each drop is called an integrant part.

(2.) An aggregate differs from a heap, because the integrant parts of the latter have no perceptible adhesion to each other, as a heap of corn. They both differ from a mixture, the constituent parts of which are of a different nature, as gun-powder.

4. There are four kinds of aggregates, arising from the different degrees of force of this attraction, acting between the constituent principles of bodies; these are the hard, the soft, the fluid, and the aeriform aggregates.

5. When the minute parts of one substance unite with those of another so intimately as to form a body, which has properties different from those of either of them, the union is called the attraction of composition. The new body is called a compound.

Examples.—Glass is a compound of sand and an alkaline salt. Sal Ammoniac is a compound of an acid and an alkali. So also is common salt.

6. The attraction of composition takes place between bodies of a dissimilar nature; and the more dissimilar they are, the greater is the force with which they combine.

7. When two or more bodies unite by the attraction of composition, one at least must be in a fluid state.

8. The compound which results from the combination of two or more bodies, possesses properties very different from those of the bodies of which is is combined.

Example.—Common salt, which is so pleasant to the taste, is a compound of muriatic acid and soda, two highly corrosive substances.

9. The principal agent employed to balance the power of attraction is heat or caloric.

10. The various substances that compose this globe are subject, on one hand, to a general law which tends to bring them together; and, on the other, to a powerful agent which tends to remove them from each other, and upon the energy of these two forces, the consistence of all bodies depends.

11. When the attraction prevails, they are in a solid state; when the caloric is most powerful, they are in a state of gas, and the liquid form is a mean between these powers.

12. Heat has a constant tendency to diffuse itself over all bodies, till they are brought to the same temperature: and by heat all kinds of bodies are expanded.

13. Heat is contained in considerable quantities in all bodies, when at the common temperature of the atmosphere: and it changes the form of bodies.

ILLUSTRATION.—Heat converts solids into liquids: and liquids into vapours, or into permanently elastic fluids. The liquid and vaporous forms of bodies are brought about in the same way with expansion, being only higher degrees of it. Hence, all bodies in nature are either solid, liquid, or in a state of elastic aeriform vapour, according to the degree of heat to which they are exposed.

14. Every body which passes from the solid to the liquid state, absorbs a portion of heat which is called latent heat.

Example.—Ice is reduced to water by absorbing a portion of heat, which, however, is not sensible, because the water produced from the ice is at first of the same temperature as that of the ice.

15. The heat which liquids absorb, when they acquire a fluid form, is again separated from them when they return to a solid state.

16. All bodies, by passing from the fluid state to the aeriform, absorb heat, which is again given out when they recover their liquid state.

17. The instruments for measuring heat by the expansion of bodies, are "thermometers" for fluids: and "pyrometers" for solids.

18. The greatest degrees of heat are produced by the burning glass, or by supplying a blow-pipe with oxygen gas.

19. The greatest degrees of cold are produced by mixing snow with certain saline substances. Common salt and snow produce a great degree of cold.

QUESTIONS FOR EXAMINATION.

1. What is chemistry?
How is the utility of this science shewn?
2. What do you mean by elective attraction?
3. What is meant by affinity of aggregation?
Give the examples.
4. How many kinds of aggregates are there?
5. What is meant by the attraction of composition?
Give the examples.
6. In what cases do the attraction of composition take place?
7. What is necessary for bodies to unite by the attraction of composition?
8. Are the properties of a compound body different from those of the bodies of which it is formed?
Give the example.
9. What is the agent employed to balance the power of attraction?
10. To what general laws are the substances that compose this globe subject?
11. What happens when attraction, and what when the caloric prevails?
12. What is the general tendency of heat?
13. What effects does heat produce?
Give the illustration.
14. In what case do bodies absorb heat, and what is it called?
Give the example.
15. In what case is heat separated from bodies?
16. In what change do liquids absorb heat?
17. What are those instruments called by which the degrees of heat are measured?
18. How are the greatest degrees of heat measured?
19. By what means are great degrees of cold produced?

LESSON THE SECOND.

LIGHT. SIMPLE SUBSTANCES.

1. Light has a considerable influence upon many chemical processes.

Examples.—All metallic oxides, especially those of mercury, lead, silver, and gold, become of a deeper colour by exposure to the sun.—Green precipitate of iron, exposed to the rays of the sun, becomes blue. Many salts will not crystallize un-

less they are exposed to the light. Many bodies, if exposed to the light, combine with it, and will, under certain circumstances, emit it again.

2. Light is an important agent with regard to vegetables.

Examples.—Many flowers follow the course of the sun, and plants that grow in houses seem desirous to get at the light. Plants that grow in the shade, or in darkness, are pale and without colour. The more plants are exposed to the light, the more colour they acquire. Vegetables are not only indebted to light for their colour; their taste and odour are derived from the same source.

3. The action of the sun's rays on the organs of vegetables, causes them to pour out streams of pure air from the surfaces of their leaves.

4. Animals droop when deprived of the light, and it appears to be of great importance to the health and happiness of human beings.

Examples.—The parts of fish which are exposed to the light, such as the back, fins, &c. are uniformly coloured; but the belly, which is deprived of light, is white in them all. Worms, grubs, &c. that live in the earth or in wood, are of a whitish colour. Birds and flying insects of the night are likewise distinguishable from those of the day by want of brilliancy of colour.

Inference.—Hence organization, sensation, spontaneous motion, and life, exist only at, or very near, the surface of the earth, and in places to which light is accessible.

5. Those substances which chemists have not been able to decompose are regarded as simple: such are light and caloric, already noticed: such are oxygen, hydrogen, chlorine, carbon, &c. such were till lately the earths, the fixed alkalies, and the metals.

6. Combustion is an important effect of caloric, but only certain bodies are subject to combustion: these are called combustible bodies.

7. Combustible bodies, when inflamed, are sources of light and heat.

8. Oxygen is only known in combination with other bodies, and cannot be obtained alone. It is absorbed by combustible bodies, and it converts them into acids.

9. Oxygen is necessary for combustion, uniting itself always to bodies which burn, augmenting their weight, and changing their properties. It is necessary also for the respiration of animals.

10. Oxygen is a constituent part of the atmospheric air, of water, of acids, and of all bodies of the animal and vegetable kingdoms.

11. Oxygen combined with light and caloric constitutes oxygen gas. In this state it approaches nearest to purity.

12. Oxygen gas, combined with hydrogen, forms water; with nitrogen, common atmospheric air; with sulphur, phosphorus, &c., sulphuric acid, phosphoric acid, &c.

13. Oxygen gives the sharp acrid character to those bodies which are called acids.

14. Oxygen combines with metals, destroys their metallic lustre, and gives them an earthy, or rusty appearance. These substances are called oxides, and they are all heavier than the metals from which they are formed.

15. Oxygen gas may be procured in a state of purity by separating it from those substances with which it is combined in nature.

16. Hydrogen is one of the constituents of water: it cannot be obtained alone, but united to caloric and light, it forms hydrogen gas.

17. Hydrogen is one of the ingredients of oils, fat, spirits, and of the component parts of animal and vegetable bodies. It is found in all animal and vegetable acids.

18. Nitrogen, called also azote, cannot be obtained in an uncombined state; but with caloric and light it is called nitrogen gas. It is one of the component parts of atmospheric air, of animal and vegetable bodies, of nitric acid and ammonia.

19. Chlorine was formerly supposed to be an acid formed with muriatic acid and oxygen, and hence it was called the oxymuriatic acid. It is now, however, known to be a simple substance. It was discovered by Sir H. Davy.

20. Chlorine is known in the gaseous state, and in combination with water.

21. Chlorine combines with oxygen, with hydrogen, and with nitrogen; and some of these combinations possess very extraordinary properties.

22. Chlorine gas is suffocating, and cannot be breathed without great injury. It supports combustion; is exceedingly powerful, corrosive and penetrating; discharges vegetable colours, burns all the metals, and when combined with water, will dissolve gold and platina. It has no action upon charcoal.

QUESTIONS FOR EXAMINATION.

1. Has light any influence in chemical processes?
Enumerate the examples.

2. In what respect is light an important agent with regard to vegetables?

3. What is the effect of the action of the sun's rays on vegetables?

4. Is light of importance to the existence of animals?
Give the examples.
What inference is drawn from this?

5. What is meant by simple substances?

6. What is combustion?

7. Of what are combustible bodies the sources?

8. What is said of oxygen?

9. How is oxygen necessary for combustion?

10. Of what bodies is oxygen a constituent?

11. What is oxygen gas?

12. What are the combinations of oxygen?

13. What gives the sharp taste to acids?

14. What effect has oxygen on metals?

15. How is oxygen gas procured?

16. Can hydrogen be obtained alone?

17. Of what is hydrogen a constituent?

18. Can nitrogen be obtained alone, and of what is it a component part?

19. What is said of chlorine?

20. How is chlorine known?

21. With what does chlorine combine?

22. What is the character of chlorine gas?

LESSON THE THIRD.

SULPHUR. PHOSPHORUS. CARBON. GASES.

1. Sulphur is a simple combustible substance, sometimes found pure in nature, but frequently in combination with metals and other substances.

2. Sulphur has a strong attraction for oxygen, and burns upon the application of fire: during combustion it absorbs a certain portion of oxygen from the atmosphere, and is converted into *sulphurous* acid.

3. If sulphur be burnt in oxygen gas it absorbs a large quantity of oxygen, and becomes *sulphuric* acid. Sulphuric acid, combined with any substance, gives a compound called a *sulphate:* thus there are sulphates of lime, iron, copper, &c.

4. Sulphur unites with the fixed alkalies, potash, and soda, and the compounds are called sulphurets of potash and soda.

5. Sulphur and iron have a strong attraction for each other; by the union, the iron becomes easy of fusion and brittle.

6. Phosphorus, another simple substance, is never met with pure in nature. It is commonly united to oxygen, in the state of phosphoric acid, which is found plentifully in different animal, vegetable, and mineral substances.

7. Phosphorus is luminous in the dark, at the common temperature of the atmosphere. It takes fire spontaneously, burns with a brilliant white flame, and is converted into phosphoric acid: phosphoric acid, combined with any other substance, gives a compound called a phosphate: hence there are phosphates of lime, &c.

8. Phosphorus is obtained by decomposing the bones of animals. It is a yellowish transparent substance, like horn or bees'-wax.

9. Phosphorus taken internally is poisonous: animals have been killed by drinking the water in which it has been kept.

10. Phosphorus easily combines with sulphur, and as the phosphorus or sulphur predominates, the compound is denominated a phosphoret or sulphuret.

11. Carbon, another simple substance, is said to exist in a state of purity in the diamond only; combined with a certain portion of oxygen it is called charcoal.

12. Charcoal is generally procured by burning wood; and when well made it is almost indestructible, neither air nor moisture affects it.

13. Carbon enters into the composition of wax, oils, gums, and resins. It combines with iron in various proportions; and the results are cast-iron and steel. What is called black-lead, used for pencils, is a composition of nine parts of carbon to one of iron, and is a carburet of iron.

14. Carbon forms a principal ingredient of carbonic acid gas, called also fixed air: this, united with other substances, produces carbonates.

15. Gases are permanently elastic æriform fluids, possessed of transparency, elasticity, and weight: they are invisible, and cannot be condensed into a solid state.

16. The air, or atmosphere, consists of a mixture of several gases, which may, by chemical processes, be obtained separately.

17. All gases are supposed to be combinations of caloric or light with certain substances, called the bases of the several gases. Some of these bases, as carbon in the diamond, are known, and may be obtained in a separate state; others, as oxygen and hydrogen, cannot.

QUESTIONS FOR EXAMINATION.

1. What is sulphur, and how is it found?

2. For what has sulphur a strong attraction, and what effects are produced by its combustion?

3. How is sulphuric acid obtained, and what is denominated a sulphate?

4. What are sulphurets?

5. What effect has sulphur on iron?

6. What is phosphorus, and where is it found?

7. What are the properties of phosphorus?

8. How is phosphorus obtained?

9. Is phosphorus harmless?
10. What is meant by a phosphoret or a sulphuret?
11. What is carbon, and in what does it exist in a state of purity?
12. How is charcoal procured?
13. Into the composition of what does carbon enter?
14. What is meant by carbonic acid, and what are carbonates?
15. What are gases?
16. Of what does the atmosphere consist?
17. Of what are gases combined?

LESSON THE FOURTH.

ATMOSPHERIC AIR.

1. The atmospheric air is chiefly composed of two gases, one unfit for the purposes of combustion and animal life, called nitrogen or azotic gas: the other eminently adapted to sustain life and combustion.

2. The chemical properties of common air are fluidity, invisibility, and the negation of all smell.

3. The fluidity of air exposes it to those frequent motions which constitute winds. The air is not capable of penetrating all bodies. Transparent substances, through which light readily passes, are secure against the impulses of the air.

4. Air, when confined in vessels, is absolutely invisible. It owes this property to the ready passage that it affords to the rays of light, which are refracted by it without being reflected.

5. The air is usually considered as insipid. Wounds, however, when uncovered and exposed to the air, are affected with an acute sense of pain. The air impedes, or absolutely prevents the growth of new bark on such vegetables as have been stripped of their covering.

6. Air is perfectly inodorous: if it sometimes affect our organs with a fetid kind of smell, it is to be attributed to the extraneous bodies that are mixed with it, as is observable in mists and vapours.

7. In the pure part of the air, or oxygen gas, a taper

will burn most brilliantly; so also will a steel or iron wire, or steel or zinc filings, exhibiting most beautiful and splendid appearances.

8. The azotic part of the atmosphere is incapable of sustaining life or combustion a single instant. An animal plunged into it must die in a moment.

9. Hydrogen gas, though very inflammable, is incapable of supporting combustion and animal life. It is often generated in mines, coal-pits, &c. and becomes mixed with atmospheric air. If by accident it comes in contact with a lighted candle, it explodes with a most tremendous report.

10. Hydrogen gas may be obtained in marshes or stagnant waters, in hot weather: but by decomposing water it is obtained in a state of perfect purity. If, for instance, water be passed over iron shavings in a state of white heat, the iron will attract the oxygen of the water, and the hydrogen gas will escape, and may be collected.

11. Hydrogen gas is 12 or 15 times lighter than common air; in contact with atmospheric air it burns with a pale blue colour. It is employed for artificial fire-works. When mixed with oxygen gas it may be exploded, like gunpowder, with a violent report. On account of its great levity it is used for filling air balloons.

12. A combination of hydrogen with carbon forms carburetted hydrogen gas: it is carbon dissolved in hydrogen. This is the gas used for lighting the public streets, shops, &c.

13. Carbonic acid gas is incapable of maintaining life or combustion. It is found in a state of combination with lime, forming lime-stone, marble, and chalk, and may be separated from them by heat, or by means of the mineral acids.

Examples.—(1.) In the burning of lime, the carbonic acid combines with caloric, and flies off in the form of gas, leaving the calcareous earth pure.

(2.) Put pounded marble, or lime-stone, into a retort, with sulphuric acid, diluted with water; the carbonic acid will be

disengaged in a state of gas, and the pure lime will combine with the acid, and form a sulphate of lime.

14. Carbonic acid gas is formed abundantly during the process of fermentation, and it occupies the empty space of the vessels containing the fermenting liquor, and when it arrives at the top it flows over. On account of its great weight it may be poured from one vessel into another like water.

15. Another curious gas is called the "gaseous oxide of nitrogen," being a combination of nitrogen with a small portion of oxygen: this gas, when mixed with atmospheric air, and received into the lungs, generates pleasurable sensations: it induces a state of great exhilaration, and an irresistible propensity to laughter.

16. Fluoric acid gas obtained from the fluate of lime, or Derbyshire spar, has a penetrating odour, and will not sustain animal life or combustion. Its most remarkable property is that of dissolving silica, and on that account it is used for etching on glass.

QUESTIONS FOR EXAMINATION.

1. Of what does the atmosphere principally consist?
2. What are the chemical properties of air?
3. What is the result of the air's fluidity?
4. Why is air invisible?
5. Is the air insipid?
6. Is pure air perfectly inodorous?
7. What will be the effect of combustion in the pure part of the air?
8. Can azotic air sustain life?
9. What are the properties of hydrogen gas?
10. Where and how may it be obtained?
11. Is hydrogen lighter than common air?
12. What is carburetted hydrogen gas, and to what use is it applied?
12. What are the properties of carbonic acid gas, and where is it found?
Give the examples.
14. In what process is carbonic acid gas found?
15. What is meant by the gaseous oxide of nitrogen and what effects does it produce?
16. From what is fluoric acid gas obtained, and what are its properties?

LESSON THE FIFTH.

EARTHS. ALKALIES.

1. All earthy and stony substances are comprehended under the general name of earths: the first nine of the following have, till very lately, been deemed simple earths: the last is one which has been but recently discovered.

Lime	Magnesia	Yttria and Thorina*
Alumina	Baryta	Glucina
Silica	Strontia	Zirconia.

The first three are the most abundant in nature.

2. Lime is found purest in marble, lime-stone, and chalk: it is, however, a principal ingredient in all shells, and in the bones of animals. It enters into the composition of marls, and it is the cement that unites the sandy particles of free-stone together.

3. All substances, in which lime is combined with carbonic acid, are called carbonates of lime. Such are marble, chalk, shells, &c.

4. Alumina, denominated also argil, or pure clay, is white, and soft to the touch; when moistened with water it forms a paste, that hardens and contracts in the fire, which renders it useful in pottery. It combines with silica, and makes mortar for building.

5. Silica, or flint, is distinguished for its extreme hardness; it is found in the purest state in free-stone, gravel, and sand. It strikes fire with steel, and is insoluble in all the acids except the fluoric.

6. Magnesia is found chiefly in stones that have a greasy feel, such as the steatite, asbestos, &c. It is obtained also from many mineral springs, and from the sea-water, in which it is combined with the acids. Thus Epsom salt is a combination of the sulphuric acid and magnesia, and is denominated the sulphate of magnesia.

* This earth was discovered by a Swedish chemist named Berzelius, in a mineral called *thorite*.

7. Baryta, the heaviest of the earths, is obtained from the ponderous spar, in which it is combined with carbonic and sulphuric acid. It is a most deadly poison: falls to powder, but greedily attracts the moisture from the atmosphere.

8. Strontia, found in Scotland, is of a greyish white colour, and when thrown into the fire it gives a beautiful red coloured flame. The other three earths are but little known.

9. The alkalies have a bitter, and highly acrid taste: they change the *blue* juices of vegetables to a *green*. They have the property of rendering oils miscible with water: they are soluble in water; form with the acids various combinations, and act as powerful caustics when applied to the flesh of animals.

10. The alkalies are either *fixed*, as potash and soda, or *volatile*, as ammonia. The former cannot be evaporated but with a very high degree of heat, the latter is evaporable at the common temperature of the atmosphere.

11. The fixed alkalies were, till within these few years, supposed to be simple bodies: the volatile alkali was supposed to be a compound of nitrogen and hydrogen; they are now found to be compounds of oxygen and metallic bases.

12. Potash is obtained from the ashes of common vegetables, and is hence denominated vegetable alkali: soda is obtained from the ashes of sea-weeds, and is called mineral, or marine alkali. Volatile alkali, or ammonia, is obtained from all animal and vegetable substances, by distillation.

13. Metals, which are very valuable on account of their durability, and of their resisting the effects of air and moisture, are the heaviest of all bodies.

14. Metals are divided into two kinds. (1.) Those which by union with oxygen produce earths and alkalies. (2.) Those which by union with oxygen do not produce either earths or alkalies. The latter of these divisions is variously subdivided, according to the relations

of the metals to the diversified objects of chemical science. They were formerly divided into three kinds. (1.) Those that are malleable, as gold, silver, copper, iron, &c. (2.) Those that are brittle, and easily melted, as bismuth, antimony, &c. and (3.) Those that are brittle and melted with great difficulty.

15. Metals become fluid by the application of heat, and in this state they imbibe the oxygen from the air, assume an earthy appearance, and are called oxides.

16. In a state of oxides metals may be dissolved in water and other fluids, in order to form dyes, colours, &c. With glass they yield substances resembling gems or precious stones.

17. Metals unite with sulphur, phosphorus, and carbon, and the combinations are called sulphurets, phosphorets, and carburets.

18. All the metals, when reduced to oxides, may be dissolved in some or other of the acids, and form solutions.

19. None of the metals except gold, silver, and copper, are found in a state of purity, but as ores; that is, mixed and blended with earths and other substances, from which they are separated with great heat.

QUESTIONS FOR EXAMINATION.

1. What do you mean by earths?
2. Where is *lime* found, and in what is it a principal ingredient?
3. What are carbonates of lime?
4. What are the properties of *alumina*?
5. For what is *silica* distinguished?
6. Where is magnesia found, and from what is it obtained?
7. What is meant by *baryta*?
8. Where is *strontia* found, and what are its properties?
9. What are the properties of the alkalies?
10. How are the alkalies distinguished?
11. Are the alkalies simple substances?
12. From what are the three alkalies obtained?
13. How are the metals described?
14. Into how many kinds are they divided?
15. What is meant by oxides?
16. In what state can metals be dissolved?
17. With what will metals unite?
18. Can all metals be dissolved?
19. In what state are metals found?

LESSON THE SIXTH.

ACIDS. SALTS. OXIDES.

1. Acids are substances which excite the taste of sourness when applied to the tongue: they change the blue juices of vegetables to red; and readily combine with alkalies, earths, and metallic oxides, forming with them substances denominated salts, or neutral salts.

2. Acids consist of a certain base united with oxygen: thus sulphuric acid is a combination of sulphur and oxygen: the oxygen is the cause of the acidity.

3. Acids which have the same base combine with oxygen in different proportions; the name of the acid is derived from the base, and this name has a different termination, according to the proportion of the oxygen combined with its base.

4. With the smaller proportion of oxygen the name ends in *ous*, and with the larger proportion it ends in *ic*: hence we have the sulphur*ous* and sulphur*ic* acids: the phosphor*ous* and phosphor*ic* acids.

5. Acids exist in the solid, liquid, and gaseous states: such are the benzoic acid, the sulphuric acid, and the fluoric, or carbonic acids.

6. Acids are of four kinds, viz. the mineral acids, as the "sulphuric acid:" the metallic acids, as the "arsenious:" the vegetable, as the "acetous," or "malic:" the animal acid, as the "phosphoric," "lactic" acids, &c.

7. Salts, in a chemical sense, are distinguished by two names, one expressive of the acid, and the other of the base.

Examples.—Sulphate of soda, or Glauber's salt, is a combination of sulphuric acid and soda: sulphate of iron, or green copperas, is compounded of sulphuric acid and iron. Muriate of soda, or common salt, is a compound of muriatic acid and soda. Nitrate of potash, or saltpetre, is composed of potash and the nitric acid: and the carbonate of lime, or chalk, marble, &c. is formed of carbonic acid and lime. "Originally the term salt was restricted to the salt with which our food is seasoned, and which has been known from the remotest anti-

quity. The new nomenclature designates it muriate of soda, upon the assumption that it consists of muriatic acid and soda. It has since, however, been more accurately called chloride of sodium; it being found in its dry state to be composed of 60 parts of chlorine, and 40 of the metallic base sodium." *Elementary Treatise on Chemistry*, published in 1839.

8. Salts composed of acids ending in *ous*, take the termination *ite* instead of *ate*: thus we have sulphites, nitrites, phosphorites, &c. Sulphur*ic* acid and lime make the sulph*ate* of lime: but sulphur*ous* acid and lime would give the sulph*ite* of lime.

9. Simple substances, united to a smaller quantity of oxygen than is necessary to form acids, are denominated oxides.

10. Metals become oxides by being exposed to great heat and the contact of the air. Metals cannot be dissolved in acids till they are combined with oxygen.

11. Sulphur, phosphorus, hydrogen, &c. have their oxides as well as metallic substances.

12. Sulphur becomes an oxide of sulphur by being kept in a melted state in the open air till it is of a reddish colour.

13. Phosphorus, when exposed to the air, absorbs the oxygen of it, and becomes first the white, then the brown oxide. With larger portions of oxygen it forms the phosphor*ous*, and phosphor*ic* acids.

14. Hydrogen, with one degree of oxygen, yields water, which is an oxide of hydrogen.

15. Animal and vegetable substances may be converted into oxides. The blood derives its red colour from the oxygen imbibed by passing through the lungs. Butter becomes rank, and meat putrefies by the absorption of oxygen; and in these states they are oxides.

QUESTIONS FOR EXAMINATION.

1. What do you mean by acids, and what are their combinations with earths, &c. called?

2. Of what do acids consist, and what is the cause of their acidity?

3. Do acids combine with different proportions of oxygen, and how are they named?

4. How are acids distinguished by their terminations?
5. In what state do acids exist?
6. How many kinds of acids are there?
7. How are salts distinguished?
Give the examples.
8. How are salts distinguished with regard to their terminations?
9. How are oxides formed?
10. How are metals converted into oxides?
11. Can other substances besides metals be converted into oxides?
12. How is sulphur converted into an oxide?
13. What changes does phosphorus undergo?
14. What is meant by the oxide of hydrogen?
15. Can animal and vegetable substances be converted into oxides?

LESSON THE SEVENTH.

COMBUSTION. WATER. MINERAL WATERS.

1. All bodies may be divided into combustible and incombustible: the term *combustible* is applied to every substance capable of being burnt in atmospheric air, or in oxygen gas.

2. Combustion is the process by which combustible bodies absorb the oxygen of the air or gas, and suffer the caloric to escape.

ILLUSTRATION.—When a combustible body is heated to a certain degree, it possesses such an attraction for oxygen, that it absorbs it from the air, while the caloric that gave it the gaseous form escapes and diffuses itself among the surrounding bodies.

3. Hydrogen, sulphur, phosphorus, carbon, silenium, boron, and the metals, are called simple combustibles.

4. Compound combustibles are such bodies as are formed by the union of two or more simple combustibles: such are coal, oils, &c. formed of hydrogen and carbon.

5. Substances that are themselves not combustible but which are necessary to the process of combustion,

are called supporters of combustion: such are oxygen gas and atmospherical air.

6. It is oxygen which gives character to the supporters of combustion, and the heat produced in burning bodies is derived from the oxygen of the atmosphere.

ILLUSTRATION.—In kindling a fire a continual stream of air flows to the burning body, which occupies the place of the air that has been decomposed, or deprived of its oxygen. Hence a continual supply of caloric is furnished by the oxygen being changed from a state of gas into that of a solid body, and incorporated with the coals. When reduced to ashes, the coals or wood may be said to be saturated with oxygen, and converted into an oxide or an acid.

7. No substance is destroyed or annihilated by combustion: the parts are separated from each other, and form new combinations.

8. The *light* or flame produced in combustion, comes from the combustible body, in which it was locked up, as it were, till raised to a sufficient temperature, when it becomes free.

9. The caloric, or heat produced, is derived from the oxygen, which being separated from the atmosphere, and united to the burning body in a solid form, gives out heat. In the same way that steam converted into water, or water into ice, must give out heat during the change.

10. Water is found in almost all natural bodies, and is either in a state of simple mixture, or in combination. In the former case it is perceptible to the eye: in the latter it exhibits no external character; and in this form it exists in crystals, salts, plants, animals, &c.

11. Water is susceptible of various forms, as the *solid* in ice; the *liquid* in what is usually called water; the *vaporous*, in steam.

12. Water is a compound of hydrogen and oxygen in the proportion of 15 parts of the former, by weight, to 85 of the latter.

13. Water may be decomposed by chemical means. (See Lesson 4. art. 10.) and it may be recomposed by the combustion of oxygen and hydrogen gases, in a glass vessel, by means of the electrical spark.

14. When water contains such an excess of any foreign matter, that it cannot be used for domestic purposes, it is called a mineral water.

15. Mineral waters generally contain the acids, the alkalies, or the salts; but the salts are most frequently to be met with, such as the sulphates of soda and magnesia.

16. The carbonates are the most common ingredients in mineral water. Chalybeate springs are composed of the carbonate of iron, united with water.

17. Muriates are very common in mineral water: the sea-water is impregnated with muriate of soda.

18. Sulphurous acid is found combined with water in the vicinity of volcanoes.

QUESTIONS FOR EXAMINATION.

1. How are all bodies divided?
2. What is meant by combustion? Give the illustration?
3. Which are the simple combustibles?
4. What is meant by compound combustibles?
5. What are the supporters of combustion?
6. What gives character to the supporters of combustion? How is this illustrated.
7. Is a substance destroyed by combustion?
8. From what does the light of a burning body proceed?
9. From what is the caloric derived?
10. In how many states is water found?
11. Of what forms is water susceptible?
12. Of what substances is water composed?
13. How can water be decomposed?
14. What is meant by a mineral water?
15. What do mineral waters contain?
16. Which are the most common ingredients, and of what are chalybeate springs composed?
17. Are muriates common, and with what is the sea-water impregnated?
18. Where is sulphurous acid found combined with water?

MINERALOGY.

OBJECTS OF THE SCIENCE, SYNOPSIS OF EXTERNAL CHARACTER OF METALS.

"All metals are minerals, but all minerals are not metals. Minerals in the restrained sense are bodies that may be melted, but not malleated."—*Bacon.*

"Our object in this chapter, as every where else in this work, will be to present facts, to account for phenomena where the causes can be traced by induction, and where our want of information leaves room to doubt, there to stop; and with such evidence or data as we can furnish, leave the reader to form his own judgment."

Introduction to the Sciences.—Walker.

MINERALOGY is that science which treats of the solid and inanimate materials of which our globe consists; and these are usually arranged under the four classes specified in the following lessons: the earthy, the saline, the inflammable, and the metallic.

The distinguishing peculiarities of these substances are as follows. The earthy minerals compose the greater part of the crust of the earth, and generally form a covering for the rest. They are not remarkable for being heavy, brittle or light coloured. They are little disposed to crystallize, are uninflammable in a low temperature, insipid, and without much smell. The saline minerals are commonly moderately heavy, soft, sapid, and possess some degree of transparency. The inflammable class of minerals is light, brittle, mostly opaque, of a yellow, brown, or black colour, seldom crystallize, and never feel cold. Metallic minerals are characterized by being heavy, generally opaque, tough, malleable, cold, not easily inflamed, and by exhibiting a great variety of colours of a peculiar lustre.

Under each of these classes, are various genera, species, and kinds, which are all noticed in their regular order by our author. Sometimes as in the vegetable kingdom we find a strict affinity between different species of minerals, and in that case in the language of the science, they are said to belong to the same family; but in mineralogy, one class does not always blend with another in a chemical point of view, or furnish that beautiful gradation and almost imperceptible union which is to be traced in the other kingdoms of nature.

As the external characters are of the first importance in

facilitating our acquaintance with minerals, and as our author has abstained from giving a detailed and synoptical description of them, I shall briefly explain this subject, considering it an appropriate introduction to the classification of the different substances which follow.

The external characters of minerals are either generic or specific. The generic characters are certain properties of minerals, without any reference to their differences, as colour, lustre, weight, &c., and the differences between these properties form the specific characters.

Generic characters are general or particular. In the first division are comprehended those that occur in all minerals, in the last, those that are found only in particular classes of minerals.

The particular generic external characters are thus advantageously arranged:

1. Colour.

2. Cohesion of particles; distinguished into solid, friable, and fluid.

In solid minerals are to be regarded the external shape, the external surface, and the external lustre. When broken, the lustre of the fracture, the fracture itself, and the shape of the fragments are to be noticed. In distinct concretions, regard must be paid to the shape of the concretions, their surface, their lustre, transparencies, streak, and soiling. All these may be ascertained by the eye. By the touch we may discover the hardness of minerals, their tenacity, frangibility, their unctuosity, coldness, weight, and their adhesion to the tongue. By the ear we distinguish their sound, and by the smell and taste, the qualities which these two senses indicate.

In friable minerals, external shape, lustre, aspect of soiling, and degree of frialibity, are to be attended to.

In fluid minerals the lustre, transparency, and fluidity are principal objects to be regarded.

The specific external characters of minerals are founded on the distinctions and varieties of the two great generic divisions. And first of colours, the names of which are derived from certain bodies in which they most generally occur, either in a natural or artificial state, or from different mixtures and compositions of both, as for instance white, this may be snow-white, reddish-white, yellowish-white, silver-white, &c. Grey, lead-grey, blueish-grey, pearl-grey, &c. Black, greyish-black, brownish-black, &c. &c. Besides these distinctions, colours may be clear, dark, light, or pale, they may have a tarnished appearance, a play, a changeability, an iridescence, an opales-

cence, a permanent alteration, and a delineation of figure or pattern, such as dotted, spotted, clouded, flamed, striped, veined, &c.

With respect to the second grand generic distinction: cohesion of particles; metals are divided into 1, Solid, or such as have their parts coherent, and not easily moveable: 2, Friable, or that state of aggregation in which the particles may be overcome by simple pressure of the finger; and 3, Fluids, or such as consist of particles which alter their place in regard to each other by their own weight.

After the external aspect, the fracture forms no inconsiderable character in minerals. Its lustre may be determined as in the external lustre; but the fracture itself admits of great varieties. It may be compact, splintary, uneven, earthy, &c. If the fracture is fibrous, we are to consider the thickness of the fibres, if coarse or allicate; the direction of the fibres, if straight or curved; and the position of the fibres, if parallel or diverging.

The external characters of metals from the senses are as follows. Those from the touch are eight in number, as already enumerated. The different characters which occur in the mineral kingdom from the sound, are a ringing sound, as in native arsenic, and their splinters of horn or stone; a grating-sound, as in fresh burnt clay; a creaking-sound, as that of natural amalgam. Those from the smell may be spontaneously emitted, and described, as bituminous, faintly sulphurous, or faintly bitter; or they may be produced by breathing on, and yield a clay-like smell; or they may be excited by friction, and smell urinous, sulphureous, garlic-like, or empyreumatic. The external character from the taste prevails chiefly in the saline class, and it contains the following varieties: a sweetish taste, sweetish astringent, styptic, saltly bitter, saltly cooling, alkaline, or urinous.

Having thus given a very brief synoptical view of the external characters of minerals, I refer the student to the important and luminously arranged propositions of our author in the following lessons.

LESSON THE FIRST.

MINERALS.

2. Mineralogy is a science, the object of which is to describe and arrange inorganic bodies; that is, all bodies which belong to our globe, except animal and vegetable substances.

2. Minerals constitute the external covering of our globe, their number is very great, and their character almost infinitely diversified.

3. The business of mineralogy consists in describing the different appearances and characters of minerals; and in arranging and classifying them according to their most obvious relations.

4. All mineral productions are comprehended in four classes: viz. the *earthy*, or stones; the *saline*, or salts: the *inflammable*, as sulphur, &c.; and metals, or *metallic* ores.

5. The *earthy* minerals contain all such as derive their qualities from the earths, (described in Lesson 5. Chemistry)·these are divided into families, or genera, according to the particular earth which predominates in each.

Example.—(1.) The silicious, or flint genus, contains all those earthy minerals in which silex or flint predominates, as the garnet, ruby, quartz, common flint, &c.

(2.) The clay genus includes common clay, slates, and all those substances that contain a predominant quantity of alumina.

6. The saline class of minerals contains all the combinations of the acids with alkalies which exist in the mineral kingdom; such are saltpetre, or nitrate of potash; common rock salt, or muriate of soda; and sal-ammoniac, or the muriate of ammonia.

7. The third, or inflammable class, comprehends all combustible bodies, except metals, and the diamond; and it includes sulphur, resins, bitumens, and graphite.

Examples.—(1.) The resin includes amber, and a substance called retinasphaltum, which seems to connect resins with bitumens.

(2.) Bitumens contain petroleum, mineral pitch, and various kinds of coal.

(3.) Graphites are true carburets of iron, of which plumbago, or black lead, used for pencils, is one.

8. The fourth class comprehends all mineral bodies, composed either entirely of metals, or of those bodies of which metals constitute the most considerable part.

9. The genera of minerals are divided into species, and these again into sub-species and varieties, according to their agreement, or difference in external qualities, as shape, colour, fracture, hardness, &c.

10. From minerals of the fourth class all metals are extracted, hence they have obtained the name of ores.

11. Metals exist in ores either in a metallic state: combined with sulphur: in the state of oxides: or combined with acids. Hence the four genera, alloys, sulphurets, oxides, and salts.

QUESTIONS FOR EXAMINATION.

1. What is mineralogy?
2. What constitutes the covering of the earth?
3. Of what does the business of mineralogy consist?
4. Into how many classes are mineral productions divided?
5. What do earthy minerals contain, and how are they divided? Give the example.
6. What does the saline class of minerals contain?
7. What does the inflammable class comprehend? Give the examples.
8. What does the fourth class of minerals comprehend?
9. How are the genera of minerals divided?
10. Whence are all metals extracted?
11. In what do metals exist?

LESSON THE SECOND.

ROCKS.

1. The stony masses of which the earth, as far as it has been explored, is composed, are either simple, (such as have been described in the last lesson) or compound.

2. Stony masses, or rocks, are very numerous, and they are found in the earth, laid one above another; so that a rock of one kind is covered by another species of rock, and this by a third, and so on.

3. This arrangement is not arbitrary, but every species of rock occupies a determinate place, so that they follow each other in regular order, from the deepest part of the earth's crust to the surface.

Example.—Lime stone is found no where under granite, but always above it.

4. Rocks are divided into five classes. The first class of rocks are covered by all the rest, but never themselves lie over any other. The others lie in order over each other.

5. These classes are denominated *formations:* hence we have PRIMITIVE; TRANSITION; FLOETZ; ALLUVIAL; and VOLCANIC *formations*, according to the period in which, and the mode by which, they have been formed.

6. The *primitive* formations are the lowest of all, and the *alluvial* constitute the very surface of the earth; for the volcanic formations are confined to particular points.

7. *Primitive* rocks are supposed to have been chemical precipitations, formed in the early chaotic state of the earth; because they never bear any trace of organized beings; these are chiefly composed of siliceous and argillaceous earths, as granite, gneiss, slate, &c.

8. *Transition* rocks were formed during the transition of the earth into a habitable state: they differ from the primitive in the variety of their colour, and by containing the remains of marine animals.

9. The *floetz* rocks are disposed in flat, horizontal strata: they contain the remains of animals and vegetables, and must have been formed after the creation of these.

10. *Alluvial* formations consist of the component parts of previously existing rocks, separated by the influence of the air, &c. and deposited in beds.

11. Alluvial formations are compounded, (1.) Of sand, gravel: and (2.) of alluvial deposit; as loam, clay, sand, turf, and calcturf. This last contains plants, roots, moss, bones, &c. which it has encrusted. The clay often contains petrified wood, and skeletons of quadrupeds.

12. Volcanic formations are of two kinds, namely, the pseudo-volcanic, and the true-volcanic: the first are minerals altered in consequence of the burning of beds

of coal situated in their neighbourhood: the second are those which have been actually thrown out of the crater of a volcano.

13. Volcanic productions consist of pumice-stones, lava, and basaltes. Pumice-stone is a kind of glass, but on account of its pores it is often lighter than water: lava is a semi-vitrified substance; and basaltes may, by heat, be converted into glass of a beautiful black colour.

QUESTIONS FOR EXAMINATION.

1. How are the stony masses of the earth distinguished?
2. How are rocks found in nature?
3. Is the arrangement of rocks arbitrary? Give the example.
4. How are rocks divided?
5. How are the classes of rocks denominated, and what is the result?
6. What is meant by *primitive* formations?
7. How are primitive rocks supposed to have been formed, and of what are they composed?
8. How have *transition* rocks been formed, and how do they differ from primitive rocks?
9. How are floetz rocks disposed?
10. Of what do alluvial formations consist?
11. Of what are alluvial formations compounded?
12. How are volcanic formations distinguished?
13. Of what do volcanic productions consist?

BOTANY.

THE EMPLOYMENT IT SUPPLIES.

——————— "At once array'd
In all the colours of the flushing year
By nature's swift and secret-working hand,
The garden glows, and fills the liberal air
With lavish fragrance."—*Thomson.*

Botany is a term derived from the Greek, for an herb or plant: and it formerly implied a knowledge of the nature,

uses, and cultivation of plants. In the accounts of the different genera, which the following lessons contain, these three objects are combined. But as a modern science, botany chiefly applies to the classification of plants; or that systematic arrangement by which, from general marks or characters, the botanist is enabled, first to trace the class, next the order, then the genus, and last of all the species, to which any plant he meets with belongs.

Various systems have been invented for the classification of the vegetable tribes: but that of Linnæus, as the simplest and most decisive, has superseded them all. It is founded on the sexual system, or that which supposes all plants to have male and female parts of generation; a system which there is every reason to believe is physiologically true, and which has been most elaborately analyzed by our author.

The flowers of plants Linnæus very properly made the sole foundation of his beautiful system of botany. Being the same in all parts of the globe capable of producing plants, the classification founded upon them affords a kind of universal language to botanists, whereby they can no longer mistake each other's meaning, as has unfortunately been the case, less or more, with almost all former botanical systems.

In investigating the genus of a plant, we must first consider its essence. The essence of every vegetable, says Linnæus, consists in the fructification; the essence of the fructification in the flower; the essence of the flower consists in the antheræ and stigma; and the essence of the fruit in the seed. Hence he makes the flower and fruit the foundation of his generic distinctions.

As it is a most convincing proof of a just and uncorrupted taste, to prefer the works of God to those of man, I am never more delighted than when I see persons of understanding busied in the cultivation of flowers. What lessons of morality are conveyed by such lovely monitors! I often think they abound no less in moral instruction, than in beauty and sweetness; which are, in truth, the very perfection of elegance: they seem equally calculated to convey instruction and delight. How deplorably stupid and perverted is that opinion which many people, who even set themselves up for persons of taste, entertain, when they look upon them as trifles utterly unworthy their notice.

The short duration of the beauty of a flower, its being subject to every blast of the inclement sky, or instantly withered by the too powerful heat of a burning sun, are the arguments which these wise people make use of, in excuse for their dis-

regard of these inimitable patterns of elegance and beauty; but, if these ungrateful beings to the beauties of nature, which are poured round us with so liberal a hand, are not incapable of being at all convinced, I would just beg leave to remind them of the uncertain state of their own prosperity; and admonish them to reflect, how little secure they are of being preserved from the oppressive storms, or of enjoying the constant sunshine of fortune; not to mention, that this objection will hold good, with equal force, against every temporal enjoyment, and all worldly satisfactions whatever. If there be, in fact, any real comparison to be drawn from human life and a flower, it certainly follows, that no person can pretend to a right of despising the one that would be thought to place any value on the other. Folly may suggest what it pleases; but there is nothing in nature unworthy of the attention of a wise person; notwithstanding all the idle wit and ridicule which the collectors of tulips, shells, and butterflies always incur; because the most inferior of her productions may, in some measure, be made instrumental to their improvement. A single leaf of the lowest herb, the smallest blade of grass which trembles in the wind, were they to consider it attentively for a few moments, would not only clear their understanding from a conceited self-sufficiency, but would improve their reason into the utmost conviction of its ignorance. An elegant author observes, "were we to reflect in a proper manner on the correlative importance of such objects as may be thought useless and insignificant, when considered only with regard to themselves, we should discover a mediate sort of union between the widest links of that infinite chain, which holds together the constitution of the universe: we should perceive that all these things which are most dissimilar in every other respect, do however agree in that common destination whereby they become so many equally important parts of one stupendous whole: and we should find as fit a place for the discovery of truth in every flower-garden, as in the celebrated gardens of Cadmus!"

There is undoubtedly, the closest affinity between a proper cultivation of a flower-garden, and the right discipline of the human mind. That industry and diligence, which are so requisite to clear a garden from its useless weeds, will naturally suggest to a thoughtful person, how much more necessary it is, to exert the same diligence in rooting from our minds their various follies, vices, and prejudices.

LESSON THE FIRST.

DEFINITIONS.

1. Botany is the science which teaches a knowledge of the vegetable kingdom; and its study includes the practical discrimination, methodical arrangement, and systematical nomenclature of vegetables.

2. According to the Linnæan system, every plant consists of a root, buds, trunk, leaves, props, inflorescence, and fructification.

3. Roots serve to fix and hold the plants in the earth, from which they imbibe nourishment. Sea-weeds afford an exception to this, for they are nourished by their surfaces, the root serving to fix them to a convenient spot.

4. A root is either annual, biennial, or perennial: the first kind live but one season, as barley or oats, the second, as wheat, survive one winter, and perish at the end of the following summer, after perfecting their seed: perennial roots remain and produce blossoms for an indefinite term of years, as trees and shrubs.

5. The body of the root is denominated the "caudex;" the fibrous part is denominated "radicula:" the latter, which is the only essential part, is annual in all cases.

6. Roots are distinguished into the "fibrous," as the grasses:—"creeping," as mint:—"spindle-shaped," as the carrot:—"stumped," as that of the primrose:—"tuberose," as the potatoe:—"bulbous," as the crocus:—and "granulated," as in the white saxifrage.

7. Buds are like the bulbs of the roots in herbaceous plants; they are guarded by scales, furnished with gum or woolliness as an additional defence. Plants are propagated by buds as well as by roots.

8. There are seven kinds of stems, or stalks of plants:—the "caulis," which bears both leaves and flowers, as the trunks and branches of trees:—the "calmus," a straw which is the peculiar stem of grasses, corn, &c.:—"scapus," a stalk that springs immediately from the

root, bearing flowers and fruit, but not leaves, as in the primrose:—"pedunculus," the flower stalk, which springs from the stems or branches, bearing flowers and fruit, but not leaves:—"petiolus," the foot stalk is applied exclusively to the stalk of a leaf:—"frons," when the leaf bears the flowers and fruit, as in the case of ferns:—and "stipes," which is seen in the stalk of a mushroom.

9. Leaves of any other hue than green are said to be coloured: their duration is mostly annual; but in evergreens they sometimes survive two or more seasons: leaves are distinguished from one another by their form and situation.

10. The form of leaves is either simple, as in grasses; or compound, as in parsley, the rose, &c.

11. The fulcra, or props, are distinguished into the "stipula," which is a leafy appendage to the herbage of plants, as in the rose:—"bractea," which is a leafy appendage to the flower or its stalk, conspicuous in the lime-tree:—"spina," a thorn which proceeds from the wood itself, as in the wild pear tree, which loses its thorn by cultivation:—"aculeus," a prickle which proceeds from the bark only, having no connexion with the wood, as in the rose:—"cirrus," a tendril intended as a support for weak stems, as in the passion flower:—"glandula," a small tumour, secreting a sweet, resinous, or fragrant liquor, as on the calyx of the moss rose:—and "pilus," a hair, which includes all the various kinds of pubescence, bristles, wool, &c.

12. There are several kinds of inflorescence, as the "whorl," in which the flowers surround the stem in a garland or ring, as in the dead nettle:—"racemus," a cluster bears several flowers, each in its own stalk, like a bunch of currants:—"spica" is composed of numerous crowded flowers, ranged along an upright common stalk; of this, wheat and barley are good examples:—"corymbus," is a flat topped spike, the long stalks of whose lowermost flowers raise them to a level with the uppermost; this is exemplified in the cabbage and wall-flower:—"fasciculus," a close bundle of flowers on little

stalks connected and level at the top, as in the sweet William:—"capitulum," a head or tuft, is composed of numerous sessile flowers, collected into a globular form, as thrift:—"umbella," consists of several stalks spreading from one centre like an umbrella:—"cyma," consists of stalks springing from one common centre, afterwards irregularly subdivided, as in the laurustinus and elder:—"panicula" is a loose subdivided bunch of flowers, arranged without order, as in the oat: and "thyrsus," a bunch, is a very dense panicle, as in the lilac.

13. Fructification comprehends not only all the parts of the fruit, but also those of the flower, which last are indispensable for the perfecting of the former.

14. The parts which constitute these organs are seven. (1.) The "calyx," or flower-cup. (2.) The "corolla," situated within the calyx, consists, generally, of the coloured leaves of flowers: it comprehends both the petal and nectary. (3.) The stamina are situated within the corolla, and are various in number in different flowers, from one to several hundreds. (4.) The pistils standing in the centre of the circle formed by the stamens. (5.) The pericarpium, or seed vessel. (6.) The seeds: and, (7.) The receptacle, which is the common base of the parts of fructification.

QUESTIONS FOR EXAMINATION.

1. What is Botany?
2. Of what does every plant consist?
3. For what are the roots designed?
4. How are roots distinguished with respect to their age?
5. How are the body and fibrous parts of roots distinguished?
6. How are roots distinguished with regard to their structure?
7. What are buds?
8. How many kinds of stems are there?
9. What is meant by coloured leaves?
10. What is the form of leaves?
11. How are the fulcra distinguished?
12. How many kinds of inflorescence are there?
13. What does fructification comprehend?
14. What parts constitute the organs of fructification?

LESSON THE SECOND.

CLASSIFICATIOF OF PLANTS.

1. The Linnæan system of botany is founded on the number, situation, and proportion of the stamens and pistils, which are usually found in the same flower, as in the lily.

2. Sometimes the stamens and pistils are placed in a different individual of the same species: that furnished with statems is called the male, or barren blossom: that with pistils the female, or fertile one. Such is the date-palm. The male and female will both produce blossoms apart, but they must be near each other before fruit can be perfected.

3. When fertile and barren flowers are borne by the same plants, such plants are named *monoecious*, as residing in the same house: the cucumber is an example.

4. If the fertile and barrren flower, that is the male and female grow on different roots, as on the date-palm, they are *dioecious*.

5. The pistil is divided into three parts, the germen, the style, and the stigma, the germen, which contains the embryo seed, and the stigma, are essential, but the style is often wanting, as in the poppy.

6. The stamen is divided into two parts, the filament and anther: the latter is essential, as containing an apparently fine dust or powder, called pollen, which, by falling on the stigma of the pistil, is the cause of complete fructification.

7. The stamens and pistils being the essential parts of a plant, Linnæus made them the basis of his system, which consists of twenty-four classes. These *classes* owe their distinctions chiefly to the stamens: the *orders*, or subdivisions of the classes are generally marked by the number of pistils.

8. The Linnæan names of the classes are

1. Monandria.	9. Enneandria.	17. Diadelphia.
2. Diandria.	10. Decandria.	18. Polyadelphia.
3. Triandria.	11. Dodecandria.	19. Syngenesia.
4. Tetandria.	12. Icosandria.	20. Gynandria.
5. Pentandria.	13. Polyandria.	21. Monoecia.
6. Hexandria.	14. Didynamia.	22. Dioecia.
7. Heptandria.	15. Tetradynamia.	23. Polygamia.
8. Octandria.	16. Monadelphia.	24. Cryptogamia.

9. The first eleven classes depend entirely upon the number of stamens: thus class 1. "Monandria," signifies one male, or one stamen. Class 2. "Diandria," two males, or two stamens, &c.

10. The twelfth class depends on the number (twenty or more) of stamens growing out of the calyx.

11. The thirteenth depends on the number growing out of the receptacle.

12. The fourteenth and fifteenth classes depend on the relations which the stamens bear among themselves: the first of these have four stamens, two long and two short, as in the thyme, and the second has four long and two short stamens, as in the stock. This last comprises the cruciform flowers.

13. The next three classes depend on the union of the stamens: in the sixteenth all the stamens are united in one sheath: in the seventeenth they are divided into two quantities; and in the eighteenth into more than two.

14. The nineteenth has the upper parts of the stamens united into a tube, and the lower parts separate.

15. The twentieth has the stamens situated on the pistil.

16. The twenty-first comprehends plants where the stamens grow in separate flowers from those that produce the seed, yet both sorts of flowers growing on the same plant, as in the cucumber.

17. The twenty-second class includes those plants in which the flowers that bear the stamens grow on separate plants from those that bear the seed, as in the date-palm.

18. The twenty-third class comprehends those plants, the stamens of which grow sometimes on separate plants, sometimes in separate flowers in the same plant, and sometimes in the same flower with the pistil.

19. In the twenty-fourth class the stamens and pistils are either not well ascertained, or cannot be numbered with certainty: this is called the cryptogamia class, and includes ferns, mosses, liverworts, flags, and different kinds of sea-weeds and fungi.

QUESTIONS FOR EXAMINATION.

1. On what is the Linnæan system of botany founded?
2. Which are the male, and which the female blossoms?
3. What are monoecious plants?
4. What are dioecious plants?
5. How is the pistil divided?
6. How is the stamen divided?
7. What did Linnæus make the basis of his system, and of how many classes does it consist?
8. Can you repeat the names of the classes?
9. On what do the first eleven classes depend?
10. On what does the twelfth class depend?
11. On what does the thirteenth depend?
12. On what do the fourteenth and fifteenth classes depend?
13. On what do the sixteenth seventeenth, and eighteenth depend?
14. How is the nineteenth class distinguished?
15. How are the stamens of the twentieth situated?
16. What plants does the twenty-first class comprehend?
17. What does the twenty-second class comprehend?
18. What does the twenty-third comprehend?
19. How is the twenty-fourth class distinguished?

LESSON THE THIRD.

OF THE ORDERS OF PLANTS.

1. The *orders* of the first thirteen classes are established upon the number of pistils, and they are designated by the Greek words monogynia, digynia, trigynia, &c. signifying one, two, three, &c. females.

Illustration.—We have in the canna, or American reed,

an instance of the monandria monogynia, that is, a flower with one stamen and one pistil. In the jasmine we see an instance of the diandria monogynia, or flower that has two stamens and one pistil. In the linum, or flax, there are five stamens and five pistils: and the flower is called pentandria pentagynia, that is, one having five males and five females, and so of the rest.

2. The orders of the fourteenth and fifteenth classes are characterized by the manner of producing seed; and those of the sixteenth, seventeenth, and eighteenth, are founded on the number of stamens which compose them.

3. The orders of the nineteenth class are marked by the united or separated, barren or fertile nature of the florets.

4. The orders of the twentieth, twenty-first, and twenty-second, are distinguished, almost entirely, by the number of their stamens.

5. The orders of the twenty-third are called monoecia, and dioecia, for reasons which have been given in the last lesson.

6. The four orders of the twenty-fourth class are ferns, mosses, flags, fungi, and liverworts.

7. The study of botany has been applied as a guide to estimate the qualities of plants.

ILLUSTRATION.—The first order of the fourteenth class, denominated "didynamia gymnospermia," are all innocent or wholesome: those of the other order are fetid, narcotic, and dangerous, being allied to a large part of the pentandria monogynia, known to be poisonous, as containing henbane, nightshade, and tobacco. The whole class tetradynamia is wholesome. Whenever the stamens are found to grow out of the calyx, they indicate the pulpy fruits of such plants to be wholesome. The papilionaceous plants are wholesome, except the seeds of the laburnum, which, if eaten unripe, are violently emetic and dangerous. Milky plants are generally to be suspected. Umbelliferous plants which grow in dry or elevated situations, are aromatic, safe, and often wholesome, while those that inhabit low and watery places are among the most deadly poisons.

QUESTIONS FOR EXAMINATION.

1. Upon what are the orders of plants established? Give the illustration.

2. How are the orders of the fourteenth and fifteenth classes characterized, and also those of the sixteenth, seventeenth, and eighteenth?

3. How are the orders of the nineteenth class marked?

4. How are the orders of the twentieth, twenty-first, and twenty-second distinguished?

5. What are the orders of the twenty-third class called?

6. What are the four orders of the twenty-fourth class?

7. To what has the study of botany been applied?

Can you give the illustration?

NATURAL HISTORY.

INTRODUCTION.

"See thro' this air, this ocean, and this earth,
All matter quick and bursting into birth.
Above, how high progressive life may go!
Around how wide! how deep extend below!
Vast chain of being! which from God began,
Nature's ethereal, human, angel, man;
Beast, bird, fish, insect, which no eye can see,
No glass can reach:—from Infinite to *Thee*,
From *Thee* to nothing." *Pope.*

THE world may very properly be considered as one large mansion, where man is permitted to enjoy the works of nature, and to adore the Almighty hand which called it into life. Blest with talents, and endowed with sense, he feels himself the lord of earth's domain: but whilst he contemplates the superiority of his station, he is too prone to forget from whom that proud station and pre-eminence is derived.

Amidst the many advantages which the mind enjoys from tracing nature through her varying course, that of finding itself raised with admiration to the power which formed it, is one of the most beneficial that can be produced: for it is impossible to behold its nice dependencies without observing an ALMIGHTY HAND.

In taking a view of animated nature, and beholding the connexion which exists in every part, we cannot but observe the exact resemblance which subsists between the human and the animal race. If Providence has bestowed upon us the gift of *intellect*, they are endowed with *sagacity* or *strength;*

and so great is the similitude in the formation of our bodies, that we might be termed animals erected on the hinder legs.

This resemblance between man and beast, though it may degrade the *body*, should elevate the *mind*, and point out the folly and absurdity of personal arrogance, when we reflect that our form bears affinity to a brute's. Man's superiority consists in knowledge, virtue, and religion; and in such a possession he may be permitted to boast and exult; there he enjoys that pre-eminent distinction which raises him above every other tribe. Leaving man in the possession of that superiority which the benevolent Author of his being has designed, I shall without further observation refer the student to the following lessons, for initiation into the principles and arrangements of that science, by which the analogy I have named is displayed and established, and the structure, uses, and habits of the inferior animals, investigated and ascertained.

LESSON THE FIRST.

THE SCIENCE DEFINED AND DESCRIBED.

1. Natural history is that part of knowledge which teaches us to distinguish and describe the objects of nature, to examine their appearance, structure, properties, and uses, and to collect, preserve, and arrange them.

2. Two objects ought to occupy the attention of the naturalist, viz. (1.) To classify natural substances, (2.) To examine their structure.

3. Few natural productions can be distinguished from others by a single property, but by a combination of several of these properties we are enabled to discriminate one object, from others which resemble it, in possessing some of those properties.

4. The principal object of natural history teaches us the characteristics, or distinctive marks of each individual natural object. This is *classification.*

5. To distinguish a *species* from all others that exist in nature, it is necessary to express in its characters almost the whole of its properties.

6. A number of species brought together constitutes a *genus* or tribe.

7. The properties which are common to all the species of the genus, combine to form the character, or rather description of the genus, distinguishing it from all those which might be formed by bringing together other species.

8. Those properties which are common to all genera, compose a character that distinguishes this assemblage or group, from all other groups. Such an assemblage is called an *order*.

9. By bringing together such orders as are nearly allied, we form a more general assemblage, called a *class;* and by the union of several classes we obtain a higher division, to which naturalists have given the name of kingdom.

10. Kingdoms, in natural history, are divided into classes; classes into orders; orders into genera; genera into species; and each species often contains several varieties.

Illustration.—Among the objects which surround us a great number are possessed of life, sensation, and voluntary motion: these we call animals, and of them the *animal kingdom* is formed. In examining various groups of animals, we find many that have four extremities, and suckle their young with teats: these are called "quadrupeds," on one account; and "mammalia," on the other, and this is a *class* of animals:—some of the mammalia have hoofed feet, blunt fore-teeth, and feed almost entirely on vegetables: these constitute an *order* of that class named *belluæ:*—a certain number of the animals of this order agree in having six fore-teeth in both jaws, and form a *genus*, distinguished by this particular from the other animals of the same order, and called the equus or horse genus. In this genus one species has solid hoofs, a tail bristly at the end, and a black mark on the shoulder of the male. This is the common ass. The varieties are distinguished by certain differences in the mane, the ears, and forehead.

11. Natural objects are usually divided into three kingdoms, the animal, vegetable, and mineral kingdoms, though there is sometimes difficulty in deciding to which kingdom certain particular substances belong.

Illustration.—There is one whole class of productions called *zoophyta*, which seem to form the connecting links between the different kingdoms. Some are connected together

in form of a stem and branches, as *corallines*, &c., and so situated as to be an exact resemblance to the seed-vessels of plants. They are very similar to sea-plants, and are generally confounded with them under the title of sea-weeds; but upon closer investigation, they are found to be living animals. Other zoophyta resemble productions of the mineral kingdom, as the madrepore and millepore, which appear like stones, or pieces of chalk or marble, but being more closely examined, there are evident marks of an organic structure.

12. Animals inhabit the exterior parts of the earth, respire, generate eggs, and are impelled to action by hunger, affection, and pain. By preying upon other animals and vegetables, they restrain within proper limits and proportions the number of both: they enjoy life and sensation, and have, in a greater or less degree, locomotion.

Illustration.—In examining the zoophyta just mentioned, it will be found that they have so much locomotion, as to be able to extend their tentacula, or feelers, in search of food; which, on the least alarm, they suddenly retract within their shell.

13. Vegetables clothe the surface of the earth with verdure, imbibe nourishment through their bibulous roots, respire by means of leaves, and continue their kind by the dispersion of seed. They are organized bodies, and have life, but not sensation.

14. Minerals occupy the interior parts of the earth, in rude and shapeless masses. They are concrete bodies, destitute of life and sensation.

15. Of these great divisions, the animal ranks the highest, in comparative estimation; next the vegetable, and the last and lowest is the mineral kingdom.

QUESTIONS FOR EXAMINATION.

1. What do you mean by natural history?
2. What are the chief objects to engage the naturalist's attention?
3. How are natural productions distinguished from one another?
4. What is meant by classification?
5. How is a species distinguished?
6. What constitutes a genus?

7. What forms the character or description of a genus?

8. What is meant by an order.

9. How is a class formed, and what is meant by a kingdom?

10. How are kingdoms, classes, &c. divided?

Can you give an illustration of this mode of classification by an example?

11. How are natural objects usually divided?

Mention some facts by way of illustration, to prove the difficulty of classing objects in their respective kingdoms.

12. How are animals described?

Illustrate in what way it can be said that zoophyta have the power of locomotion.

13. Give the description of vegetables.

14. Where are minerals found, and how are they described?

15. In what order do the three natural kingdoms rank in comparative estimation?

LESSON THE SECOND.

OF THE ANIMAL KINGDOM, OR ZOOLOGY.

1. The animal kingdom is divided into *six classes*, the characters of which are taken from the internal structure of the beings treated of: and each of the classes is divided into orders.

ILLUSTRATION.—A considerable portion of the bulk of animals is composed of tubular vessels which originate in a heart. The heart propels either a colourless transparent fluid, or a red blood, into the extremities of the veins, through which it returns to the origin of motion. One of the distinguishing characteristics of the classes arises from the colour and temperature of the blood.

2. The six classes are denominated mammalia, aves, amphibia, pisces, insecta, vermes.

3. The mammalia, or first class, includes all animals that suckle their young: viz. man, quadrupeds, whales, seals, porpoises, and the bat tribe.

4. The mammalia are characterized by having a heart with four cavities, viz. two ventricles and two auricles: the blood is red and warm, and the animals belonging to it are *viviparous*, or bring forth their young alive and perfect.

ILLUSTRATION.—The senses of the mammalia consist of the organs of sight, hearing, tasting, and smelling, and the power of feeling. In many of these animals the organs are of greater acuteness than in man. The eyes in some quadrupeds, the hearing in others, and the sense of smell in others, are far more acute than those possessed by the human race. In some quadrupeds the eyes are furnished with a membrane, semi-transparent, which may at pleasure be drawn over the ball of the eye for its defence. The nose is more or less compressed or lengthened. In the elephant it is extended in a most wonderful manner into a long trunk, at the tip of which are placed the nostrils. The tongue in quadrupeds is usually of a flattened and lengthened shape. In some it is of a cylindric shape, and lengthened into the form of a worm, and is extensile at the pleasure of the animal.

5. The class aves, or birds, is distinguished from the mammalia by being oviparous, or that bring forth their young by means of eggs.

6. Amphibia, or amphibious animals, have a heart with one ventricle, and one auricle: their blood is cold and red. They breathe by means of voluntary lungs.

7. The amphibia, by the peculiar structure of their respiratory organs, have the power of living either in water or air. This class includes reptiles, serpents, and the shark, skate, and a few others, usually denominated fishes, but which possess this peculiarity.

8. The class pisces, or fishes, resembles the amphibia in the structure of the heart and the quality of the blood; but it is distinguished from them by having branchiæ, or gills, instead of voluntary lungs.

9. Insecta, or insects, have a heart, with one ventricle and no auricle: the blood is cold and white, and the animals are furnished with antennæ, or feelers.

10. The character of the class vermes, or worms, is the same as that of insects, only that the animals have no antennæ, but are furnished with tentacula.

SUMMARY.—(1.) The internal structure of the mammalia and aves is the same; and they differ in this, that the former are viviparous; the latter oviparous.

(2.) The internal structure of the amphibia and pisces is the same; but the former are endowed with voluntary lungs, the latter have external gills.

(3.) The internal structure of the insecta and vermes is the same, but the former are antennæ, the latter tentacula.*

QUESTIONS FOR EXAMINATION.

1. How is the animal kingdom divided, and from what are the distinctive characters of the classes taken?

Give the illustration.*

2. How are the six classses denominated?

3. What does the first class include?

4. How are they characterized?

5. How is the class aves distinguished from the mammalia?

6. What is the character of the amphibia?

7. What does the amphibia include, and why are they enabled to live either on land or in water?

8. In what does the class pisces differ from the amphibia?

9. What is the character of the class insecta?

10. In what do the vermes differ from insects?

Give me the summary respecting the six classes.

Point out the distinction between the antennæ and palpi in insects, and the tentacula of vermes. See note.

LESSON THE THIRD.

MAMMALIA.

1. The class mammalia is so named from being provided with teats for the purpose of suckling their young. They resemble man in their structure: most of them are quadrupeds, and with man, inhabit the surface of the earth. The largest, though fewest in number, inhabit the ocean.

2. The mammalia are distributed into seven orders, the characters of which are taken from the number, situation, and structure of their teeth.

3. The names of the seven orders are, primates, bruta, feræ, glires, pecora, bellua, and cete.

* The antennæ of insects are distinguished from the tentacula of the vermes, in being *crustaceous;* and from the palpi of insects, by their situation being nearer the mouth: the antennæ of insects rarely exceed two. They have sometimes been confounded with tentacula under the general name of feelers, but the true feelers of insects are the palpi. The *antennæ* are processes, or jointed bodies, situated on each side the head: the *palpi*, or feelers, are short jointed processes proceeding from the mouth.

4. The order primates contains man, monkies, and bats; they have four front cutting teeth in both jaws, and two pectoral teats. The genera of this order are homo, simia, lemur, and vespertilio.

5. The genus homo, or man, includes two species, denominated by Linnæus, homo sapiens, and homo monstrosus: the first species contains several varieties, as the wild man, the American, European, Asiatic, and African. The second includes the Patagonian, Hottentot, &c.

6. The genus simia, or monkey tribe, contains sixty or seventy species, separated into four distinct divisions; viz. (1.) Apes which have no tail. (2.) Baboons whose tails are short. (3.) Monkies whose tails are long. And (4.) Monkies whose tails are long and prehensile.

7. The simia genus resembles man in the uvula, eyelashes, hands, feet, fingers, toes, &c., but it differs from him in the want of reason: the individuals have retentive memories, are imitative, and full of gesticulations: chatter with their teeth, and grin: they are filthy, thieving, gregarious; and the prey of leopards and serpents.

Illustration.—No animal approaches so nearly the human form, or is so strongly impressed with the human likeness as the ourang-outang, or wild man of the woods. The animals of this species reside in the warmer parts of India, Africa, and in some of the Indian islands, where they roam about to the great terror of the negroes, who dare not pass through the woods alone for fear of being attacked and overpowered by them. The ears, the hands, and the feet, bear a strong resemblance to the human, and the body, which is lightly covered with hair, scarcely differs from that of a man, except that there are no calves to his legs. He walks erect, feeds upon fruits, and sleeps under trees. When the negroes leave a fire in the woods, this creature will sit close to it as long as any embers are left remaining. In its wild state the ourang-outang is a most formidable creature, but when domesticated he becomes gentle and obedient, and capable of imitating a variety of actions.

8. The lemur, or macauco genus, consists of animals approaching to monkies in the form of their feet; but

differing from them in their manners. Some of the species are without tails, and some have long tails.

ILLUSTRATION.—The lemur tardigradus, or loris, walks and climbs with great slowness; and it is supposed incapable of leaping. Its manners are gentle and interesting, it is extremely susceptible of cold. It sleeps from sun-rise to sunset without intermission, is very attentive to cleanliness, licking its rich fur like a cat. Its food consists generally of fruits, but there are species of insects which form a repast peculiarly gratifying to it, and the sight of them excites in its countenance the most glowing animation, and summons to exertion all the energies of its frame.

9. The vespertilio genus have palmated fore-feet, with a membrane surrounding the body, giving the animal the power of flight.

10. The animals of this tribe fly abroad by night, by means of the membrane above described: they feed on gnats and nocturnal insects: they are torpid during winter in cold countries, gathering together in dark caverns, sticking to walls, or suspending themselves by the hind legs: they have the additional sense of being able to avoid objects in their way when deprived of eyes.

ILLUSTRATION.—When bats are taken in the torpid state, and brought into a warm room, they gradually recover from their torpor. Bats are sometimes seen in such large flights as to darken the atmosphere, and some kinds, as the spectre bat, are so voracious as to attack men and other animals while they are asleep, perforate some large vein, and gorge themselves with the blood. The bats of this country live chiefly on insects, which induces them to frequent the sides of woods, or to glide along the surface of the water. By the ancients the bat was consecrated to the goddess of the infernal regions, and its general aspect, nocturnal flights, and leathern wings, render it not an unappropriate inhabitant of those obscure and dismal territories. The fabulous harpies of the ancients must have originated from a similar source. The larger bats of Africa and India answer extremely well to the general description of those monsters.

QUESTIONS FOR EXAMINATION.

1. From what do the mammalia derive their name, and how are they described?

2. Into how many orders are they distributed, and from what is their character taken?

3. What are the names of the seven orders?

4. What does the order primates contain: what is their character; and of what genera does it consist?

5. What does the genus homo include?

6. What does the simia genus contain, and how is it divided?

7. In what does this genus resemble man, and in what does it differ from him?

Can you give any illustration of this genus?

8. Of what does the lemur genus consist, and in what respects does it agree and disagree with the monkey tribe?

Give some account of the lemur tardigradus.

9. How is the vespertilio genus characterized?

10. Describe their habits.

Give some account of the bat in writing.

LESSON THE FOURTH.

MAMMALIA.

1. The order bruta has no fore-teeth in either jaw; and it includes eight genera, viz. the sloth, rhinoceros, elephant, platypus, &c.

2. The sloth inhabits the warmer parts of America; feeds on fresh leaves, lives in trees, never drinks, is fearful of rain; climbs easily, walks painfully and slowly, hardly travelling fifty yards in twenty-four hours; its cry is wretched, and its tears excite pity.

3. The rhinoceros inhabits marshy places between the tropics, lives on thorns and spinous plants: may be tamed, but when enraged, it will in its fury overturn trees; its sight is weak, but its sense of smell is very acute. There are two species, viz. the *one*-horned and *two*-horned rhinoceros.

4. The generic character of the elephant is tusks in the upper jaw: proboscis very long and prehensile: body nearly naked.

ILLUSTRATION.—The elephant inhabits the torrid zone, in swampy places, and by the sides of rivers; feeds on the leaves and branches of trees: devours grain voraciously; is

gregarious, docile, long-lived, and sagacious. The proboscis is long, and capable of extension and contraction, furnished at the end with a hook, serving the purpose of a hand, with which it takes its food and drink: it serves also as the organ of respiration. It will carry houses on its back, moves quickly, swims dexterously; is used in war by the Indians, and was formerly armed by the Romans with scythes. This is the largest of quadrupeds: its height is from nine to twelve feet, and it sometimes weighs four or five thousand pounds. His tusks extend very far beyond the mouth; they resemble horns marked with curled fibres. These are the ivory of the shops, and some weigh 150lbs. each.

5. The platypus is a newly discovered animal that has a mouth shaped like the bill of a duck: and palmated feet.

ILLUSTRATION.—This is the most extraordinary of all the mammalia class: it exhibits the perfect resemblance of the beak of a duck engrafted on the head of a quadruped. The peculiarity of its bill and webbed feet proves that it must be a resident in watery situations:—that it has the habit of digging, or burrowing in the banks of rivers, or under ground, and that its food consists of aquatic plants and animals.

6. The animals of the order feræ have, for the most part, six conical fore-teeth in each jaw: it contains ten genera, among which are the seal; the dog; the cat; the bear; the hedgehog, &c.

7. This order consists of predacious animals, whose sharp, hooked claws, and sharp fore-teeth, manifest their habits. They are all endowed with a keen sight, and have strength and agility combined to dart upon their prey, and to retain it with a firm grasp.

8. The phoca, or seal genus, is dirty and quarrelsome: the individuals are easily tamed: their skin and fat are useful: they inhabit and swim under water, and crawl on land with difficulty: feed on fish and marine productions, and swallow stones to prevent hunger, by distending the stomach.

9. The phoca-ursina inhabits Kamtschatka, New Zealand, and the adjacent islands: swims impetuously in large families; the old ones live by themselves and grow fat: each has a particular stone for its bed, which it never deserts: the males fight fiercely in defence of

their females and stations: when grieved they shed tears plentifully.

10. The canis, or dog genus, is characterized as voracious, tearing what it devours, swift in its course, but cannot climb trees, because its claws are not retractile.

ILLUSTRATION.—Of all animals the most faithful is the dog; he fawns at the appearance of his master, and defends him: he runs before him on his journey, and if the road divides, looks back; he is docile, and seeks for what is lost, watchful by night, gives notice of the approach of strangers, and watches over what is committed to his care. He drives home cattle from the field; keeps them within bounds, and guards them from wild beasts. He points out game, and brings what is killed to his master. He is made to turn spits and to draw small carriages. He abhors beggars, bites strangers, licks wounds, howls at music, is liable to diseases and madness, and communicates the latter by biting. He has an exquisite sense of smell.

The wolf, a species of the canis genus, hunts in packs and destroys cattle; is very suspicious, being hardly heard in the woods; will not pass through a door, but leaps over the fence; dreads the sound of a trumpet: is exquisite in the sense of smelling; patient of extreme hunger and cold; devours man, and even his own species.

The jackal species prowl by night in flocks of 200 each; they attack and feed on lesser animals: at the cry of one, all within hearing howl hideously, and urge other beasts to hunt the stag, &c., while the lion or tiger lying in wait, seizes the prey, and as the king of the forest, satisfies his hunger, leaving to the crouching jackal the remainder; hence the story of the jackal being the lion's provider.

11. The felis, or cat genus, has retractile claws, and easily climbs trees: it is temperate in its habits; very swift, and sees best by night. The lion and tiger are species of the felis genus.

ILLUSTRATION.—The lion inhabits Africa: it is sometimes found in the deserts of Persia, India, and Japan. It preys on horses and other large quadrupeds; and, when pressed by hunger, on man. It is afraid of flame; is restrained by dogs; easily tamed when young: it roars horribly; sleeps in the sun; eats every third day; and its flesh is eaten by the Americans. The tiger inhabits the warmer parts of Asia, China, Japan, and India, lives in woods and thickets, near rivers. It

is cunning, cruel, strong, of vast swiftness, infesting and desolating man. When tamed from his birth will exercise his ferocity as soon as liberated; the male destroys its own progeny; will even attack a lion; it bounds from ambush upon its prey, and is the most beautiful of wild beasts.

12. The animals of the glires order have two cutting fore-teeth in each jaw: their feet are formed for running and bounding, and they live on the bark of trees, roots, vegetables, &c., which they gnaw. The beaver, guinea-pig, rats, mice, and hares, are of this order.

Illustration.—(1.) The beaver inhabits the northern parts of Europe, Asia, and America: it feeds on the bark and leaves of trees: it walks slowly, swims dexterously, sleeps profoundly, is very cleanly, and conveys the food to its mouth with its fore-paws; cuts down trees with its teeth, erects convenient houses, lives in families, from which they dismiss such as are indolent, who become hermits. In the structure of its house it far exceeds the ingenuity of all other quadrupeds.

(2.) The lemming is a species of the mouse genus, and inhabits the mountains of Norway and Lapland: it feeds on grass, and burrows under the snow in the winter; before the approach of a hard frost it migrates in immense armies, and always in a straight line, chiefly by night, in spite of every obstacle, even rivers and houses. The lemmings destroy all vegetation in their progress and lay waste the country through which they pass. They will even attack man; and in turn they themselves become the prey of birds, beasts, and many reptiles, so that few return in the spring to the mountains.

13. The animals of the pecora order have many cutting teeth in the lower jaw, but none in the upper. They live on herbs, and chew the cud; they have four stomachs; viz. the "paunch," to macerate and ruminate the food; the "bonnet," to receive it: the "omasus," of numerous folds, to digest it: and the "abomasus," to give it acescency, and prevent putrefaction: the camel, the stag, the goat, the sheep, and the ox, are of this order.

Illustration.—(1.) The Arabian camel, or dromedary, inhabits the temperate deserts of Arabia, Asia, and Africa: in many places it is domesticated, and is mild and gentle. It is very useful in conveying heavy burdens over the dry sandy deserts, and will carry 1,200 pounds weight. It moves slowly,

and cannot be forced beyond its accustomed pace, nor be made to carry more than its usual burden. It is patient of hunger and thirst, and will travel many days without water. It kneels down to be loaded or unloaded at the command of its keeper. The hair of the camel is very valuable, and the flesh and milk are eaten by the Arabians. The Bactrian camel is chiefly used by great men; there is a breed of these in China, of such swiftness, that they are called camels "with feet of wind."

(2.) The ox genus inhabits various parts of the world; and the several species are used for draught and burden; and are likewise valuable for their flesh, milk, hides, and many domestic purposes. They are subject to a variolous disease, which may be communicated to the human race, and thereby, it is hoped, prevent future infection from the small-pox. The animals of this genus are infested by gad-flies, lice, and other insects: they are poisoned by yew, hemlock, aconite, and anemone.

14. The animals of the belluæ order have obtuse fore-teeth and hoofed feet; their motion is heavy; for food, they gather vegetables. They are of great value to mankind, and are used for draught, burthen, and the saddle. They have the singular property of breathing only through the nostrils, and not through the mouth. The horse, the hog, and the hippopotamus are of this order.

Illustration.—(1.) The horse is naturally timid, swift, and vigilant. Horses in a state of nature move in flocks, having a leader before, with its ears thrown forwards, and a sentinel behind with its ears bent backwards, to guard against surprise both ways. The ass is a species of the equus, or horse genus: from the male ass and mare the mule is produced; and from the horse and female ass the hinny is produced. From the skin growing on the back of the ass, shagreen is manufactured.

(2.) The hippopotamus inhabits the lakes of Abyssinia and Ethiopia: it feeds by night on vegetables and roots of trees. It frequently lays waste whole plantations of sugar-cane, rice, and other grain. It walks slowly, but swims dexterously, and walks under water, but cannot remain long without rising to the surface for breath.

15. The animals of the cete order have fins instead of feet: the tail is horizontal and flattened: they have no

nostrils, but instead of these a fistulous opening in the upper part of the head; they feed on fish and inhabit the ocean. The monodon; balæna, or whale; physeter, and dolphin are the genera included in this order.

ILLUSTRATION.—These are arranged with the mammalia from their similarity of structure, though their habits and manners are like those of fish. Their heart has two auricles and two ventricles: they have warm blood; their lungs respire alternately: their eye-lids are moveable, ears hollow, receiving sound through the medium of the air, and they suckle their young.

QUESTIONS FOR EXAMINATION.

1. What is the characteristic of the bruta order, and what animals does it include?

2. What are the characteristics of the sloth?

3. What is said of the rhinoceros?

4. What is the generic character of the elephant?

Give some account of the illustration.

5. What is the platypus?

Give the illustration.

6. What are the characteristics of the animals of the feræ order?

7. Of what does this order consist?

8. What is said of the seal?

9. What are the peculiarities of the phoca-ursina?

10. How is the dog genus characterized?

Give some account of the illustration.

11. How is the cat genus distinguished?

What is said of the lion and tiger?

12. How are the animals of the glires order characterized?

Give an account of the beaver and lemming.

13. By what characteristics are the animals of the pecora order distinguished?

What is said of the dromedary and ox?

14. How are the animals of the belluæ order distinguished?

What is said of the horse, mule, &c?

What facts are given with respect to the hippopotamus?

15. How is the cete order characterized?

Why are they arranged with the mammalia?

LESSON THE FIFTH.

AVES.

1. The second class includes birds, and is denominated aves: it consists of animals having a body covered with feathers or down. Their jaws are protracted and naked; they have two feet, and two wings formed for flight.

2. The feathers of birds are convex above, and concave beneath; they vary in colour according to age, sex, season, or climate; their eggs are various in number, size, and colour, but always covered with a calcareous shell, deposited in an artificial nest, and hatched by the genial warmth of the parent.

3. Birds are mostly monogamous, or live in single pairs; upon defect of food or warmth they migrate into milder climates; and some are supposed to become torpid in the winter.

4. The generic characters are taken from the bill, tongue, nostrils, cere, caruncles, and other naked parts: they are divided by Linnæus into six orders.

5. The first order, denominated "accipitres," includes birds of prey; as vultures, eagles, hawks, owls, &c. The birds of this order have an angular projection in their upper mandible.

Illustration.—The condor, a species of the vulture genus, is of a vast size, measuring with the wings extended, from 12 to 16 feet; it builds under the projections of the highest rocks; lays two white eggs; preys on birds, kids, lambs, calves, and has been known to carry off children ten years of age. Two of them are said to be able to destroy and devour a cow; when passing near the ground it makes a tremendous noise.

6. The second order, denominated "picæ," or pies, contain all the birds of the crow and jay kind, parrots, wood-peckers, kingfishers, &c. The bill of the birds of this order is compressed and convex. There are three divisions of the order distinguished by their feet, as formed for perching, climbing, and walking.

7. The third order, called "anseres," or web-footed birds, include the swan, goose, and duck tribe; gulls, penguins, and many others. They have a bill broad at the tip, and covered with skin: the two divisions are distinguished by the bill, in some it is toothed, in others it is without teeth.

8. The birds denominated "grallæ," or waders, make the fourth order, and are distinguished by a roundish bill and fleshy tongue: there are two families, viz. those with three toes, and those with four toes.

This order consists of all the heron tribe, the curlews, and plovers, and others, which have lengthened legs, and which frequent watery situations.

9. The fifth order is denominated "gallinæ," or such birds as are more or less allied to the common domestic fowl. They have a convex bill, and the upper mandible is arched. This order includes the pheasant and partridge tribe, the peacock, turkey, and a variety of other birds.

ILLUSTRATION.—The pheasant tribe, in its wild and natural state, is found in India: it is domesticated every-where, and subject to innumerable varieties in colour and size. It feeds on grains and worms. The argus pheasant, so remarkable for size and beauty, is a native of Sumatra, and is considered as constituting one of the chief ornaments of European museums. In China there is a species of pheasant known to us only from the long tail feathers, which are sometimes brought over, and which are six feet long: this bird has been thought to have been noticed by Marco Polo, who speaks of pheasants with tails measuring ten spans in length.

10. The sixth order is named "passeres:" the birds of this order have conic and sharp-pointed bills. It comprises pigeons, thrushes, larks, finches, and small birds in general, either with thick, or slender bills; and it is separated into four distinct divisions: viz. those having thick bills: those having an upper mandible somewhat hooked at the point: those with a notched upper mandible: and those with a straight, simple, and tapering bill.

QUESTIONS FOR EXAMINATION.

1. Of what does the class aves consist?
2. What is said of the feathers and eggs of birds?
3. How do birds live?
4. From what are the generic characters of birds taken?
Give some account of the condor.
5. What is the first order of birds, and what does it include?
6. What is the second order, and how is it distinguished?
7. What is said of the third order?
8. How is the fourth order distinguished, and into what families are they divided?
9. What is said of the order gallinæ?
What is said of the pheasant?
10. How is the sixth order characterized, and what does it comprise?

LESSON THE SIXTH.

AMPHIBIA. FISHES.

1. The third class of animals is denominated "amphibia," from their appearing to live promiscuously on land or in water.

2. This class is divided into two orders, viz. reptiles and serpents: and it includes tortoises, frogs, lizards, and serpents, all of which possess a kind of voluntary power, by which they are able, at pleasure, to suspend their respiration, so as to continue for a long time without breathing.

3. Reptiles are characterized by breathing through their mouths; and by having feet, and flat naked ears: of this order are frogs, lizards, and tortoises.

4. Serpents are distinguished as being without feet, but frequently armed with a deadly poison, contained in fangs resembling teeth. In cold and temperate climates they conceal themselves, in winter, in cavities beneath the surface of the ground, where they become torpid.

5. Some serpents are viviparous, as the rattle-snake, the viper, &c.; but those which are innoxious are

oviparous, depositing their eggs in a kind of chain, in a warm situation, where they are afterwards hatched.

6. The broad laminæ on the bellies of serpents are termed scuta, and the smaller, or divided ones beneath the tail are called scales, and from these the genera are characterized.

FISHES.

7. The fourth class of animals includes all kinds of fishes, which are distinguished by the swiftness of their motion, and the voraciousness of their appetites.

8. Fishes breathe by means of gills, and swim by fins: they are mostly covered with cartilaginous scales, and are furnished with an air bladder, by the contraction and dilation of which they can raise or sink themselves in the water at pleasure.

9. They live on mucus, insects, worms, dead bodies, lesser fish, or sea-plants.

10. The under, or belly fins, called ventral fins, are to be considered as analogous to the feet in quadrupeds, and from the situation, presence, or absence of these fins, the Linnæan division of fishes are instituted.

11. There are five orders of fishes, viz. the apodes; jugulares; thoracici, abdominales, and cartilaginous fishes.

12. Fishes entirely destitute of fins, such as the eel, gymnotus, &c. are denominated "apodes," and are included in the *first* order.

Illustration.—The fins are thus named, the pectoral, the ventral, the anal, the caudal, or tail; and the dorsal or back fins.

13. The *second* order of fishes, denominated "jugulares," have their belly or ventral fin placed more forward than the pectoral or breast fin.

14. The *third* order, called "thoracici," have their ventral fin immediately beneath their breast fins.

15. The "abdominales," or fourth order, have the ventral fins situated behind the pectoral fins.

16. *Fifth* order includes cartilaginous fish, which were separated into two orders by Linnæus, viz. the

branchiostegous, or fishes that have gills without bony rays, and the chondropterigious, or those that have cartilaginous gills, the sucker belongs to the former, and the squalus, or shark to the latter.

ILLUSTRATION.—(1.) The cyclopteri inhabit the sea, feed on worms, insects, and the fry of other fish, and are furnished beneath the ventral fins with an oval aperture of a muscular substance, and edged with small threaded appendages, by means of which they have the power of adhering so firmly to the rocks, as to be moved by scarcely a less force than would destroy them.

(2.) Sharks are inhabitants of the sea; they give a luminous appearance at night: some of them grow so large as to weigh two or three thousand pounds: from the liver is extracted much oil: the skin is used for polishing wood, ivory, &c. They are mostly solitary, devouring whatever comes in their way: they bring forth their young alive, each enclosed in a square, pellucid, horny case, terminated at the four corners by very long slender filaments, which are generally twisted round corallines, sea-weed, or other fixed substances.

QUESTIONS FOR EXAMINATION.

1. What is the *third* class of animals called, and from what do they derive their name?
2. How is this class divided, and what does it include?
3. How are reptiles characterized?
4. How are serpents distinguished?
5. How are the venomous ones distinguished from those that are innoxious?
6. Which are the scuta and scales?
7. What does the *fourth* class include?
8. How are fishes described?
9. On what do they live?
10. How are the Linnæan divisions of fishes instituted?
11. What are the five orders of fishes?
12. How is the first order distinguished?
13. What is the characteristic of the second order?
14. How are the fins situated in the third order?
15. How are the fins situated in the abdominales?
16. What does the fifth order include?

Give the illustration.

LESSON THE SEVENTH.

INSECTS.

1. The fifth class in the Linnæan system consists of insects, which are small animals furnished with several feet, and which breathe by a kind of spiracles, or breathing holes, distributed in a row on each side of the abdomen: the head is furnished with a pair of antennæ, or horns.

2. Insects have generally four, sometimes two or six, feelers affixed to the mouth: the mouth is usually placed beneath the head: they have two or four wings: the upper ones are often crustaceous shells, covering the lower: their legs consist of three divisions.

3. The sexes of insects are male, female, and neuter: the latter are devoted to labour for those of the more perfect sex.

4. Most insects undergo a triple metamorphosis, or transformation, effected by casting off the different coats or coverings in which the perfect insect is enclosed.

5. The first state in which insects appear is that of an egg: from the egg is produced the "larva," grub, or caterpillar, without wings, slow in its motion, sometimes with many feet, and sometimes with none: from this state it passes into that of the "pupa," chrysalis, or nymph, and escaping from this it becomes a "perfect insect."

Illustration.—The eggs are usually deposited beneath the surface of some clod, and the larva, when first hatched, is not more than the eighth of an inch in length, gradually advancing in growth, and changing its skin till it arrives at the length of nearly two inches: it now prepares for the change into a chrysalis, or pupa, selecting for the purpose some small clod of earth, in which it makes a house, and, after a certain time, throws off the last skin, and appears a pupa; in this it continues till the succeeding summer, when the beetle emerges from its retirement, commits its depredations, and deposits its eggs in a favourable situation, and having so done it soon dies. The larva of the beetle tribe is eagerly sought for by

hogs, poultry, &c. but if it appear in very considerable quantities in the autumn, it is said to prognosticate an epidemic disorder. The *Scarabæus auratus,* or golden beetle, is a species of great beauty.

6. Insects are the least of the animal creation, and excepting aquatic ones, as the lobster, &c. and a few others, they are annual, that is, finish their term of existence in the space of a year or less.

7. Insects are said to inhabit those plants on which they feed, and they often take their trivial names from their habitations.

Illustration.—In the genus curculio we have the nut weevil, a small brown insect, with an extremely long and slender snout. This insect is the parent of the maggot in the hazel nut. In August the female insect perforates the rind of the nut, and deposits her egg, and when the kernel is almost ripe, the egg is hatched, and the maggot feasts on the food ready prepared for it. By the time it is fully grown the natural fall of the nut takes place, and the animal creeps out, burrows under ground, where, after a certain time it casts its skin, and commences pupa or chrysalis. In this state it remains all winter, till the following August, when it emerges from its concealment, and appears in its complete form.

8. Insects are divided into seven orders: the first contains all the insects of the beetle tribe, or such as have strong horny sheaths, or covers to their wings: this order is called "coleoptera," or sheath-winged insects. All beetles are of this order.

Illustration.—The coleopterous insects form a very extensive order, and each genus is distinguished by some leading particularity of appearance. In the individuals of the order the real or proper wings are of a membranaceous nature, and when not in use, are curiously folded up under the exterior strong or horny sheaths.

9. The second division or order of insects is denominated "hemiptera," or half-winged, because the upper part of the wing sheaths, in this tribe, is of a leathery texture, and the lower part membranaceous. Locusts, grasshoppers, cicadæ, lantern flies, &c. are of this order.

10. The third order is denominated "lepidoptera," or scaly winged; it consists of the insects commonly

termed butterflies and moths. The powder on the wings is found to consist of minute scales of various shapes and sizes: these are disposed in the manner of slates on the roof of a building, lapping over each other.

11. The fourth order is denominated "neuroptera," or nerve-winged, on account of the reticulated appearance of the wings. This order includes dragon-flies, &c. The insects of this division have always four wings.

Illustration.—The libellula, or dragon-fly, is an extremely ravenous insect, and is usually seen hovering over stagnant waters: the larvæ are six footed, very active, and inhabitants of the water, they prey with the most rapacious ferocity upon aquatic insects and the larvæ of others: the pupa resembles the larva, but has the rudiments of wings.

12. The "hymenoptera," or fifth order, consists of insects with four membranaceous wings, and a sting, or a process resembling one. Bees, wasps, &c. are of this order.

13. The sixth order is denominated "diptera," and contains such insects as are furnished with two wings only: such are flies properly so called, gnats, and a great variety of other insects.

14. The seventh order is called "aptera," and consists of insects that are totally destitute of wings, as spiders, scorpions, centipedes, crabs, lobsters, fleas, mites, &c.

Observations.—(1.) Some of the coleopterous insects are destitute of wings, and yet are not of the apterous order.

(2.) In some species of insects one sex is winged and the other apterous, as in the case of some of the moth tribe: in the lampyris noctiluca, or glow worm, the female is apterous, or without wings, and emits a beautiful phosphoric light, for the purpose of attracting the male, which is winged, and of the order coleoptera. The aphides in the order hemiptera are some of them winged, and some wingless.

QUESTIONS FOR EXAMINATION.

1. Of what does the fifth class in the Linnæan system consist?
2. How are insects described?
3. What is said of the sexes of insects?
4. What kind of metamorphosis do insects undergo?

5. Through what states or stages do insects pass?
6. Which are the least subjects in the animal creation?
7. What is said of the habitations of insects?
Give the illustration.
8. Into how many orders are insects divided, and what is the first order?
How is this subject illustrated?
9. What is the *second* order, and how is it described?
10. What is the *third* order, and of what does it consist?
11. How is the *fourth* order denominated, and what does it include?
Give the illustration.
12. Of what does the *fifth* order consist, and what is it called?
13. What is the *sixth* order, and why is it so named?
14. Of what does the *seventh* order consist, and what is its name?
What observations are made on this class of animals?

LESSON THE EIGHTH.

VERMES, INCLUDING CONCHOLOGY.

1. The *sixth* class in the Linnæan system is denominated "vermes." It includes not only worms, but those animals which have the general character of being slow in motion, of a soft substance, extremely tenacious of life, capable of re-producing such parts of their bodies as may have been taken away or destroyed, and inhabiting moist places.

2. This class is divided into five orders, and they are principally distinguished by their tentacula or feelers. They are generally considered as the lowest scale of animated nature.

3. Most of the animals in this class are imperfect when compared to quadrupeds, possessing neither eyes, ears, head, nor feet. Many of them, as the corals and corallines, approach to the vegetable tribe, and some of them resemble, at least in their coverings, productions in the mineral kingdom.

4. The *first* order of the class vermes is denominated "intestina," of which some of the individuals live within other animals; some in the waters, and a few in the earth.

ILLUSTRATION.—The "ascarides" inhabit the intestines of the human body: the "gordius" perforates clay to give a passage to springs, and the "lumbricus," or earth-worm, perforates the common soil, which it renders fit to receive rain. It is the food of moles, hedgehogs, and various birds.

5. The second order is denominated "mollusca:" the animals of this order are naked, furnished with tentacula, or arms, of which the limax or slug is a good illustration.

ILLUSTRATION. (1.)—The animals of the mollusca order are exceedingly numerous: many of them are inhabitants of the sea, and serve as food to thousands of the more useful and important species of fish. Some of them emit a phosphorescent light, like the glow-worm, and, with other living insects give a beautiful brilliancy to the sea. The starfish are of this order.

(2.) The cuttle fish, also of this order, possess the power of expelling a black fluid in considerable quantities, so as to discolour the water, to favour their escape when pressed hard by an enemy. This liquor was used as ink by the ancients; and is said to be the basis of modern Indian or Chinese ink. The bone in the back is converted into powder, and is used as pounce for paper, and as an excellent cleanser, and preservative for the teeth.

6. The third order is named "testacea:" these are molluscæ covered with calcareous shells which they carry about with them; of this order is the common garden snail, or "helix hortensis."

7. The study of this branch of natural history is denominated *Conchology*. There are more than a thousand species of shells, some of which, on account of their beauty and rarity, bear a very high price.

8. Shells are separated into three divisions, the multivalve, bivalve, and univalve, according as the shells consist of *many* parts: *two* parts, or of a single piece.

9. The multivalve consists of many plates or shells connected in some species, like the different parts of a coat of mail.

The barnacle, consisting of several small shells at the hinge of two large shells, is in this division.

10. Bivalves consist of two shells, connected by a hinge, as the cockle, muscle, oyster, scallop, &c.

ILLUSTRATION.—Oysters and muscles are found in beds, and may be improved by artificial management. They deposit their spawn, a jelly-like substance, which adheres to stones, and is soon covered with a shell.

Pearls are sometimes found in oysters and in muscles. These are little calcareous concretions, formed of the same liquid, secreted by the animal, of which the inner surface of the shell is composed, and seem to be the effect of accidental injury. When the internal surface of the shell is abraded, the pearly excresence is formed to repair the injury. Hence the Chinese have learnt to increase the number of pearls, by catching the muscles, perforating the shells, and abrading the inner surface; they then replace the muscles in the water, and after a certain time fish up the same again, and upon opening them discover pearls attached to the point of the wire with which the shell was abraded.

11. The univalves comprehend those that have a regular spire, which is a most numerous division, including the snail, periwinkle, &c.; also the gowrie, a beautiful spotted shell very common as an ornament on chimney-pieces: and those without a regular spire.

ILLUSTRATION.—The substance of the shells of this order of animals, when chemically examined, is found to be a mild calcareous earth, deposited in a mass of net-work composed of animal matter. Every part is secreted by the animal itself: the whole surface of the animal being concerned in the formation of the shell. The shining matter left in the tracks of snails, is that very substance, which when deposited in strata one above another, hardens by exposure to the air, and forms a shell.

12. The fourth order is named "zoophyta:" the animals of this order are composite, holding a place between animals and vegetables. Most of them take root and grow up into stems, multiplying life in their branches, and deciduous buds, and in the transformation of their animated blossoms or polypes, which are endowed with spontaneous motion.

ILLUSTRATION.—Sponge is an animal production and of this order; every minute pore on the surface of a perfect piece of sponge was the orifice through which a polypus-kind of animal extended his feelers in search of food. Sponge, when first fished up from the sea, is gelatinous, or a glue-like sub-

stance, and requires repeated washing in fresh water before it is fit for the several purposes to which it is applied.

13. Plants resemble zoophytes, but are destitute of animation and locomotion: zoophytes are plants, but furnished with sensation, and the organs of spontaneous motion.

14. Of the order zoophyta, some are soft and naked, and are called "zoophytes;" others are covered with a hard shell, and are denominated "lithophytes."

ILLUSTRATION.—Large beds or rocks composed of the animal productions of this division are formed at the bottom of the sea. They derive their nutriment from insects, and from the saline and other matters in the sea. These, in their turn, are the origin of many of the chalk-beds, calcareous rocks, lime-stones, and other mineral articles.

15. The fifth order of the class vermes is called "infusoria," which are extremely minute animalculæ, destitute of feelers, and generally invisible to the naked eye. They are chiefly found in infusions of various vegetable substances.

ILLUSTRATION.—The vorticella is found in most stagnant and impure water, and is known by its constant rotatory motion. Rain water collected in cisterns of almost any kind, and kept for some time, contains myriads of them.

The hydra, or fresh water polypus, another animalcule of this order, is found in almost every pool of water. It resembles a hollow tube attached by its smallest extremity to some stone, stick, leaf, &c. in the water, and furnished with feelers at the other extremity, which it can extend in search of food. The young ones appear as excrescences, on the surface of the parent, and in time stretch out like branches, and each becomes a distinct animal. The polypus is propagated by division, for being cut in pieces, in every direction, each piece will in a very short time produce a perfect animal. This mode of production forms an example of the gradations made by nature in stepping from the animal to the vegetable world.

QUESTIONS FOR EXAMINATION.

1. What is the sixth class in the Linnæan system, and what does it include?

2. How is this class divided?

3. What is said with regard to the imperfections of these animals?

4. What is the *first* order of these animals, and where do they inhabit?

Give the illustration?

5. How is the *second* order characterized?

Are the animals of the mollusca order very numerous, and what is said of them?

What is said of the cuttle fish?

6. What is the *third* order?

7. To what study does the order testacea give rise?

8. How are shells separated?

9. Of what do the multivalves consist?

10. What are bivalves?

What is said of oysters and muscles?

In what are pearls found, and how are they formed?

11. What do univalves comprehend?

What is said of the substance of shells?

12. What is the *fourth* order of the class vermes, and what is said of the animals comprehended in it?

What is said of sponge?

13. In what respects do plants and zoophytes resemble one another?

14. How are the zoophyta distinguished?

What is said in illustration?

15. What is the *fifth* order called, and how is it described?

Where is the vorticella found?

What is said of the hydra, or the fresh water polypus?

ANATOMY AND PHYSIOLOGY.

ON THE CIRCULATION OF THE BLOOD.

"The blood, the fountain whence the spirits flow;
The gen'rous stream that waters ev'ry part;
And motion, vigour, and warm life conveys
To ev'ry particle that moves and lives."—*Armstrong.*

In the materials of the human frame
What num'rous wonders might we quickly name:
Let it suffice that I describe a few
And treat the student with a brief review.

PHYSIOLOGY is the doctrine of the constitution of the works of nature. By this definition, physiology must necessarily

have for its object, the explanation of that internal organical economy in plants or animals, which nature has devised for the preservation of the individual, and for the continuance and propagation of the species. It is divided into the particular and general. The particular, which treats of the properties of the individual or species, constitutes the science of ANATOMY, and the general, treats of those properties and functions which belong in common to all living bodies.

Attending minutely to a living body, which has already escaped from the seed, we may observe, that, in order to live, it must be allowed the free use of air, as applied to the organs of *respiration*. That in order to grow, it must likewise have a supply of food; and which, on being received into the system, is prepared by *digestion*; taken up by absorption; distributed by circulation; assimilated by *nutrition*; and the whole carried on by means of *secretion*. We again perceive, that these functions are all dependent on a general principle, *irritability*; by which the system is rendered by stimulation susceptible of *motion*; accommodates itself to different circumstances by means of *habit*; alters its shape by successive *transformations*; produces the species by *generation*; and, after many a languid affection from *sleep*, is at last subjected to the general fate of all bodies, Death. These are considered to be the general properties of living bodies.

The contemplations of the student are now directed in this the last division of our work to the HUMAN FABRIC; and here the science of Anatomy, analyzed in the succeeding lessons, discovers to us ten thousand wonders and beauties which the narrow limits prescribed to these introductory essays preclude me from mentioning: indeed, it would not be possible, in a performance of this kind, to explain adequately the geometrical and mechanical accuracy with which the AUTHOR OF NATURE has constructed every part of the body, to carry on the animal economy, and answer the various purposes of life. All that I can propose to perform in this short essay, is by briefly touching upon the nature and wonders of the phenomenon I shall attempt to elucidate, *the circulation of the blood*, to aid the intentions and forward the purposes of the author, and to give the student some little insight into the matter, as an inducement for him to study the principles and propositions of the following lessons with attention, and to set apart a portion of his leisure time for the purpose of acquiring a further acquaintance with anatomy.

Though it is common to talk familiarly of the circulation of the blood, yet perhaps very few are acquainted with it:

I shall therefore appropriate this introduction to the purpose of a brief, though I hope an intelligible, description of the manner in which the circulation is performed. This important secret was brought to light by WILLIAM HARVEY, an English physician, a little before the year 1600: and when it is considered thoroughly, it will appear to be one of the most stupendous works of matchless skill.

To form a distinct judgment of the mechanism and importance of the circulation, it will be necessary to describe the structure of the arteries, veins, and nerves; and take notice of some experiments made upon them; and then must be considered the cavities of the heart, by means of which the blood is propelled through the body. To these I now proceed.

The arteries are blood-vessels consisting of a close texture of strong elastic fibres, woven in various webs, laid in different directions, and interspersed with an infinity of delicate nerves, veins, and muscular arteries. They are divided and subdivided into numberless branches and ramifications, that become smaller and smaller as they recede from the heart, until at last their extremities are found much more slender than the hairs of our heads, (and are therefore called capillary arteries,) which either unite in continued pipes with the beginnings of the veins, or terminate in small receptacles, from which the veins derive their origin. The arteries have no valves, but only have their trunks springing from the heart: they throb and beat perpetually whilst life remains; their extremities differing in the thickness of their coats and some other particulars, according to the nature of the path which they pervade. All the arteries in the lungs (except the small ones that convey nourishment to them) are derived from the great pulmonary artery, which issues from the right ventricle of the heart. And all the arteries in the rest of the body proceed from the aorta, (which obtained this name, because the ancients thought it contained air only,) whose trunk springs from the left ventricle of the heart.

The veins resemble the arteries in their figure and distribution; but their cavities are larger, and their branches, perhaps, more numerous. Their coats are much weaker and more slender than those of the arteries. They are furnished with several valves, contrived in such a manner as to permit the blood to pass freely from the smaller into the larger branches, but to stop its retrogression. They neither throb nor beat. Their beginnings form continued pipes with the extremities of the arteries, or arise from some gland or receptacle where the arteries terminate. All the veins in the

lungs, from their capillary beginnings growing still larger, unite at last and discharge their blood into the left auricle of the heart: and all those in the rest of the body empty themselves in like manner into the vena cava, which opens into the right auricle of the heart.

The nerves deduce their origin from the brain, or its appendages, in several pairs of a cylindric form, (like so many skeins of thread with their respective sheaths,) which in their progress decrease by endless divisions and subdivisions, until at last they spread themselves into a texture of filaments, so slender, and so closely interwoven with each other over the whole body, that the point of a needle can hardly be put upon any part of it, without touching the delicate branch of some nerve.

It has been found by many trials, that when an artery is laid bare, and a ligature made upon it, if it be opened with a lancet between the ligature and the heart, the blood will rush out with great violence; and a rapid jerking stream will continue (if not stopped by art,) until through loss of blood the animal faints or dies. But if the same artery be opened between the ligature and extremities, a few drops only will ooze out from the wounded coats.

On the other hand, when a vein is laid bare, and a ligature made upon it, if it be opened between the ligature and the extremities, the blood will gush out, as we see in common venesection. But, if the same vein be opened between the binding and the heart, no blood will appear. From these experiments it is obvious to the slightest attention, that the blood flows from the heart, through the arteries, to the extreme parts of the body; and returns again through the veins to the heart.

For the regular performance and continuation of this motion of the blood through all the different parts of the body, the heart, which is the *primum mobile*, giving the first impulse, is furnished with four distinct muscular cavities, that is, with an auricle and a ventricle on the right side, and an auricle and a ventricle on the left. Through these cavities, curiously adapted to their respective offices, the blood circulates in the following order: it is received from the veins, first into the right auricle, which, contracting itself, pushes the blood into the right ventricle at that instant dilated. The moment this ventricle is filled it contracts itself with great force, and impels the blood into the pulmonary artery, which passing through the lungs, and returning by the pulmonary veins, is received into the left auricle of the heart, and from

thence it is pushed into the left ventricle; which being thus filled, contracts itself, and drives the blood with great rapidity to all the parts of the body, and from them it returns again through the veins into the right auricle of the heart, as before.

It is very remarkable, that we have here a double circulation: one, from the right ventricle, *through the lungs*, to the left auricle of the heart, in order to convert the chyle into blood, and finally to prepare it for the nourishment of the animal; the other, from the left ventricle, *through the whole body*, to the right auricle of the heart, which serves to supply that nourishment to every part, besides various other purposes.

But to proceed, of these four muscular cavities, the two auricles are contracted at the same instant, while the two ventricles are dilated; the ventricles in their turn are contracting themselves at the very instant that the auricles are dilating. The arteries, in like manner, beat in alternate time with the ventricles of the heart.

The nerves, as well as the veins and arteries, act their part in this rotation of the blood; for if the eighth part of the nerves which proceed from the brain to the heart be bound up, the motion of the heart immediately languishes, and soon ceases entirely.

Thus we have a species of *perpetual motion*, which none but a Being of infinite wisdom and power could produce; yet whose continuation requires the constant aid of the same hand that first gave it existence. The brain transmits animal spirits to the heart, to give it a vigorous contraction. The heart, at the same time, pushes the blood into the brain to supply it with new spirits: by which means the head and the heart give a continual and mutual support to each other. But this is not all; the action of the heart sends the blood and other vital humours over the whole body by the arteries, and distributes nourishment and vigour to *every part*, (while, perhaps, the animal spirits from the extremities of the nerves return again into the blood,) and the whole refluent mass is conveyed back through the veins into the heart, which enables it, without intermission, to persist in rolling this *tide of life*. But here it must not be supposed that the arteries pass on to the extremities of the limbs, before they communicate with the returning veins: for upon this supposition, after an amputation has been performed, whatever blood might be brought to the stump by the arteries, it is certain, none of it could be carried back again to the heart: because the intercourse between the heart and the limbs would, in this case, be entirely cut off. But the all-wise AUTHOR of our being has

provided for this exigency, by forming a great number of less branches from the larger arteries, which constantly communicate with corresponding branches of the returning veins. And hence, it is easy to conceive how the circulation is carried on after amputation has been performed.

With respect to the velocity of the circulating blood, and the time in which the whole quantity thereof has undergone a complete circulation; although several amputations have been made, the matter is not decisively settled. Dr. Irwin, Dr. Keill, and M. Brande, have most distinguished themselves in enquiries of this nature; but they are far from agreeing in their conclusions. The substance of the calculations and experiments of the two former may be seen in Dr. Rees's improved edition of Chamber's Cyclopædia: and of that of the latter, in a treatise written expressly upon the subject.

In conclusion, from what little has been advanced in this short essay, the unprejudiced young student will I trust find a striking display of the wisdom and goodness of our Almighty Creator. To those who hold to the negation of such a Being, I scarcely know what to say; for they who live, move, think, and act, must be left without excuse, if they deny or forget God, or refuse to honour or be thankful to Him. Those who withstand the evidence of the works of nature, when properly observed, are not likely to be convinced by rational deductions; but will probably continue infidels, (unless their hearts be changed by Divine grace,) until they are convinced of their fatal mistake, by experiencing the indignation of that Almighty Being whose existence they have so impiously denied.

But this I sincerely hope will not be the case with any of the youthful perusers of this small volume. However, in this sceptical and latitudinarian age, when every part of divine truth is questioned, opposed, and alas! too frequently holden in derision, it becomes us to be wary; and not only so, but to join in a general endeavour to persuade those who are deviating from the true path speedily to return thereto.

LESSON THE FIRST.

THE BONES.

1. Anatomy is a science which explains the structure, disposition, and use of every part of the human body.

2. The human body consists of solids and fluids.

The solids consist of bones, muscles, vessels as channels for the various fluids, nerves, and viscera.

3. The BONES are the most compact and solid parts of the body, and serve for the attachment and support of all the other parts.

4. The bones are firm, hard, and perfectly insensible; they are divided into the long and cylindrical, and the flat.

5. There are 248 separate bones in the human body, which when connected with wires, &c. make up the artificial skeleton.

6. There are eight separate bones in the skull; that serve as a sort of vault in which the brain is enclosed.

7. The vertebræ of the neck, so called from the ease with which they move, are separated from one another by an elastic substance. They support the head, which is by their means readily moved up and down, and turned round on either side as far as is necessary.

8. The principal bones in the trunk are the *breast-bone*, to which the seven true, and five false ribs are fastened: the *spine* which extends from the skull to the end of the loins and serves to lodge and defend the spinal marrow: the *pelvis* intended to support the abdomen, and the *thorax* reaching from the neck to the end of the breast-bone, which serves as a chest, or place of safety, for the heart, lungs, &c.

QUESTIONS FOR EXAMINATION.

1. What is meant by the term anatomy?
2. Of what does the human body consist?
3. How are the bones and their uses described?
4. Into what classes are they divided?
5. How many bones are there in the human body?
6. How many bones are there in the human skull, and for what do they serve?
7. What is said of the vertebræ of the neck?
8. Which are the principal bones of the trunk, and what are their uses?

LESSON THE SECOND.

THE MUSCLES, ARTERIES, VEINS, AND CIRCULATION OF THE BLOOD.

1. The muscles constitute the flesh; they are susceptible of contraction and relaxation, and are with the help of the tendons, the instruments of animal motion.

2. The muscles are either *voluntary* or *involuntary*. The motions of the former are subject to the will, as in the case of the arms, legs, &c. &c.

3. The heart is a hollow muscle, and that, as well as the stomach, intestines, &c. act upon their contents by means of muscular fibres; but they are called involuntary muscles, because their motions do not depend on the will.

4. Each large muscle consists of two parts, viz. the belly, which is the active part, and its cord-like extremities called tendons. The muscles are fastened to the bones by the tendons, and they perform their action by contracting both ends towards the centre.

5. The red colour which distinguishes the muscular or fleshy parts of animals is owing to the vast number of blood-vessels, that are dispersed through their substance.

6. The nerves are long, white, medullary cords that originate in the brain and spinal marrow, and serve for sensation. *Sensibility*, therefore, depends on the nerves: *motion*, on the muscles.

7. The nerves conduce to all the enjoyments and sufferings of life, and to the intellectual faculties of man; the muscles are the chief support of animal life, and the source of all the bodily powers.

8. The heart is the principal organ of life: it contains four cavities for receiving the blood, and giving it a fresh impulse through the arteries.

9. The arteries originate in the heart, and through them the blood is carried from the heart to every part of the body, for the preservation of life, generation of heat, nutrition, and the secretion of the different fluids.

10. The pulse felt at the wrist, temples, and various parts of the body, is occasioned by the reciprocal action of the heart and arteries, when the blood is driven from the heart into the arteries to be distributed through the whole body.

11. The arteries terminate in small, and to the naked eye, invisible veins, which bring back the blood from the extremities to the heart.

12. All the veins originate at the extremities of the arteries; they continually increase in size as they approach the heart: they do not pulsate, but the blood which they receive from the arteries they carry back with a slow motion, and it is prevented from returning by valves, of which there are a great number.

13. The double circulation of the blood is this: *one* from the heart to the lungs, for the purpose of receiving oxygen from the air: the other over all the parts of the body, to give out its nutritive and vital properties to the whole machine.

QUESTIONS FOR EXAMINATION.

1. What are the muscles, and what are their use?
2. How are they classed?
3. What are the involuntary muscles, and how do they act?
4. Of what do the muscles consist, and by what, and how do they perform their motions?
5. To what is the red colour of the muscles owing?
6. What are the nerves, and for what do they serve?
7. How are the nerves and muscles described?
8. What is the heart and its uses?
9. What purposes do the arteries serve?
10. How is the pulse occasioned?
11. How do the arteries terminate?
12. Give a description of the veins.
13. Explain the double circulation of the blood.

LESSON THE THIRD.

THE BRAIN AND THE NERVES.

1. The brain, which is a small pulpy mass of a whitish colour, occupies all that cavity which is formed by the eight bones of the skull.

2. The spinal marrow is a continuation of the brain, which passes out of an opening in the skull, and runs down the canal of the back-bone, giving out nerves in its passage.

3. All the nerves run out in pairs, but they soon separate, and spread over the whole body.

4. The brain and nerves constitute entire the organs of feeling and sensation, the other parts of the body being of themselves incapable of feeling.

5. All excitement to action, produced by the will, proceeds from the brain and spinal marrow, through the medium of the nerves.

6. The nerves are the organs; the brain, the receptacle of all our sensations, the source of all our ideas.

QUESTIONS FOR EXAMINATION.

1. How is the brain described, and where is it situated?
2. What is the spinal marrow?
3. How are the nerves situated?
4. What purposes do the brain and nerves serve?
5. How is voluntary action excited?
6. What is remarked of the nerves and brain?

LESSON THE FOURTH.

THE STOMACH. LIVER. DIGESTION, &c.

1. The stomach is shaped like a bag, and is the grand receptacle for the food, where it is retained until it is changed by *digestion.*

2. The stomach has two openings, the *one* called the æsophagus, through which the food passes into it; the *other* intended to carry away the digested substance, is called the intestinal canal.

3. The chief agent in digestion is the *gastric juice;* by the muscular nature of the stomach, the food when properly digested is propelled through the intestinal canal into the intestine, which is a membraneous tube, four or five times the length of the person in which it is.

4. The food in its digested state is called *chyme,* and in this state it enters the intestine, where it undergoes another change, and the *chyle,* a milk-like substance, is separated from it.

5. The *chyle* is that substance from which the blood is formed, and it is absorbed by the mouths of the lacteal vessels, which are every where distributed in intestines, while the feculent parts of the chyme and the bile are drawn into the large intestine, by which it is expelled from the body.

6. The liver is formed for the secretion or separation of the bile from the blood, which passes into the *ductus hepaticus,* and thence into the gall-bladder, where it is kept till it is wanted to mix in the intestine.

7. The chief uses of the bile are, 1, to extricate the chyle from the chyme; and 2, to excite the peristaltic motion of the bowels.

8. The lacteals convey the chyle from the intestine into the jugular vein, that empties itself into the heart.

9. The kidnies are two glandular substances, intended to drain the system of its redundant water: for this purpose a considerable portion of the blood is perpetually passing into each kidney, where it leaves its superfluous water, and then returns into the circulation by means of a particular vein.

10. The water thus strained from the blood is carried by canals, called uretærs, into the bladder, into which it passes, through its two coats, which answer the purpose of a valve, to prevent the possibility of regurgitation.

QUESTIONS FOR EXAMINATION.

1. Give a description of the stomach?
2. What are the openings of the stomach, and for what are they intended?
3. What is the chief agent in *digestion*, and how is the process carried on?
4. What is meant by the terms *chyme* and *chyle*?
5. What is the use of the *chyle*, and how is it carried away?
6. Of what use is the liver?
7. What are the chief uses of the bile?
8. Where do the lacteals convey away the chyle?
9. How are the kidnies situated, and what is their use?
10. How is superfluous water carried away?

THE END.

KNIGHT, PRINTER, UPPER HOLLOWAY, MIDDLESEX.